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THE COLOR OF WATER.*

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THE literature on the color of water is widely scattered; it appears not to have been read by anybody; and it is somewhat contradictory. It has, therefore, seemed desirable to collect the material in an accessible form as it constitutes an interesting chapter in the general subject of the colors of colloids.

Tyndall [1] has discussed the blue color of turbid media with special reference to the color of the sky and of the sea. In Newton's rings the color nearest to the central black spot is a faint blue—blue of the first order—corresponding to the film of air when thinnest. "If a solid or liquid, of the thickness requisite to produce this color were broken into bits and scattered in the air, Newton inferred that the tiny fragments would display the blue color. Tantamount to this, he considered, was the action of minute water-particles in the incipient stage of their condensation from aqueous vapor. Such particles suspended in our amtosphere ought, he supposed, to generate the serenest skies. Newton does not appear to have bestowed much thought upon this subject; for to produce the particular blue which he regarded as sky-blue, thin plates with parallel surfaces would be required. The notion that cloud-particles are hollow spheres, or vesicles, is prevalent on the Continent, but it never made any way among the scientific

* Communicated by the Author.

[1] "Fragments of Science: The Sky; Voyage to Algeria; Niagara."

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men of England. De Saussure thought that he had actually seen the cloud-vesicles, and Faraday, as I learned from himself, believed that he had once confirmed the observation of the illustrious Alpine traveler. During my long acquaintance with the atmosphere of the Alps I have often sought for these aqueous bladders, but have never been able to find them. Clausius once published a profound essay on the colors of the sky. The assumption of small water drops, he proved, would lead to optical consequences entirely at variance with facts. For a time, therefore, he closed with the idea of vesicles, and endeavored to deduce from them the blue of the firmament and the morning and evening red.

"It is not, however, necessary to invoke the blue of the first order to explain the color of the sky; nor is it necessary to impose upon condensing vapor the difficult, if not impossible, task of forming bladders, when it passes into the liquid condition. Let us examine the subject. Eau-de-Cologne is prepared by dissolving aromatic gums or resins in alcohol. Dropped into water, the scented liquid immediately produces a white cloudiness, due to the precipitation of the substances previously held in solution. The solid particles are, however, comparatively gross; but, by diminishing the quantity of the dissolved gum, the precipitate may be made to consist of extremely minute particles. Brücke, for example, dissolved gum-mastic, in certain proportions, in alcohol, and carefully dropping his solution into a beaker of water, kept briskly stirred, he was able to reduce the precipitate to an extremely fine state of division. The particles of mastic can by no means be imagined as forming bladders. Still, against a dark ground—black velvet for example—the water that contains them shows a distinctly blue color. The bluish color of many liquids is produced in a similar manner. Thin milk is an example. Blue eyes are also said to be simply turbid media. The rocks over which glaciers pass are finely ground and pulverized by the ice, or the stony emery imbedded in it; and the river which issues from the snout of every glacier is laden with suspended matter. When such glacier water is placed in a tall glass jar, and the heavier particles are permitted to subside, the liquid column, when viewed against a dark background, has a decidedly bluish tinge. The exceptional blueness of the Lake of Geneva, which is fed with glacier water may be due, in part, to particles small enough to

remain suspended long after their larger and heavier companions have sunk to the bottom of the lake.

"We need not, however, resort to water for the production of the color. We can liberate, in air, particles of a size capable of producing a blue as deep and pure as the azure of the firmament. In fact, artificial skies may be thus generated, which prove their brotherhood with the natural sky by exhibiting all its phenomena. There are certain chemical compounds—aggregates of molecules—the constituent atoms of which are readily shaken asunder by the impact of special waves of light. Probably, if not certainly, the atoms and the waves are so related to each other, as regards vibrating period, that the wave-motion can accumulate until it becomes disruptive. A great number of substances might be mentioned whose vapors, when mixed with air and subjected to the action of a solar or an electric beam, are thus decomposed, the products of decomposition hanging as liquid or solid particles in the beam which generates them. And here I must appeal to the inner vision already spoken of. Remembering the different sizes of the waves of light, it is not difficult to see that our minute particles are larger with respect to some waves than to others. In the case of water, for example, a pebble will intercept and reflect a larger fractional part of a ripple than of a larger wave. We have now to imagine light-undulations of different dimensions, but all exceedingly minute, passing through air laden with extremely small particles. It is plain that such particles, though scattering portions of all the waves, will exert their most conspicuous action upon the smallest ones; and that the color-sensation answering to the smallest waves—in other words, the color line—will be predominant in the scattered light. This harmonizes perfectly with what we observe in the firmament. The sky is blue, but the blue is not pure. On looking at the sky through a spectroscope, we observe all the colors of the spectrum; blue is merely the predominant color. By means of our artificial skies we can take, as it were, the firmament in our hands and examine it at our leisure. Like the natural sky, the artificial one shows all the colors of the spectrum, but blue in excess. Mixing very small quantities of vapor with air, and bringing the decomposing luminous beam into action, we produce particles too small to shed any sensible light, but which may, and doubtless do, exert an action on the ultra-violet waves of the spectrum. We can watch these particles,

or rather the space they occupy, till they grow to a size able to yield the firmamental azure. As the particles grow larger under the continued action of the light, the azure becomes less deep; while later on a milkiness, such as we often observe in nature, takes the place of the purer blue. Finally the particles become large enough to reflect all the light-waves, and then the suspended 'actinic cloud' diffuses white light. . . .

"In the harbor of Gibraltar, on the morning of our departure, I resumed a series of observations on the color of the sea. On the way out a number of specimens had been collected, with a view of subsequent examinations. But the bottles were claret bottles, of doubtful purity. At Gibraltar, therefore, I purchased fifteen white glass bottles, with ground-glass stoppers, and at Cadiz, thanks to the friendly guidance of Mr. Cameron, I secured a dozen more. These seven and twenty bottles were filled with water, taken at different places between Oran and Spithead. And here let me express my warmest acknowledgments to Captain Henderson, the commander of *H.M.S. Urgent*, who aided me in my observations in every possible way. Indeed, my thanks are due to all the officers for their unfailing courtesy and help. The captain placed at my disposal his own coxswain, an intelligent fellow named Thorgood, who skilfully attached a cord to each bottle, weighted it with lead, cast it into the sea, and, after three successive rinsings, filled it under my own eyes. The contact of jugs, buckets, or other vessels was thus avoided; and even the necessity of pouring out the water, afterward, through the dirty London air.

"The mode of examination applied to these bottles has been already described. The liquid is illuminated by a powerfully condensed beam, its condition being revealed through the light scattered by its suspended particles. Care is taken to defend the eye from the access of all other light, and, thus defended, it becomes an organ of inconceivable delicacy. Were water of uniform density perfectly free from suspended matter, it would, in my opinion, scatter no light at all. The track of a luminous beam could not be seen in such water. But an amount of impurity so infinitesimal as to be scarcely expressible in numbers, and the individual particles of which are so small as wholly to elude the microscope, may, when examined by the method alluded to, produce not only sensible, but striking, effects upon the eye.

"The results of the examination of nineteen bottles filled at various places between Gibraltar and Spithead are here tabulated:

"Here we have three specimens of water, described as green, a clearer green and bright green, taken in Gibraltar Harbor, and off Cabreta Point. The home examination showed the first to be

TABLE I.

No.	Location	Color of Sea	Appearance in Luminous Beam
1	Gibraltar Harbor	Green	Thick with fine particles.
2	Two miles from Gibraltar	Clearer green	Thick with very fine particles
3	Off Cabreta Point	Bright green	Still thick, but less so.
4	Off Cabreta Point	Black-indigo	Much less thick, very pure.
5	Off Tarifa	Undecided	Thicker than No. 4.
6	Beyond Tarifa	Cobalt-blue	Much purer than No. 5.
7	Twelve miles from Cadiz	Yellow-green	Very thick.
8	Cadiz Harbor	Yellow-green	Exceedingly thick.
9	Fourteen miles from Cadiz	Yellow-green	Thick, but less so.
10	Fourteen miles from Cadiz	Bright green	Much less thick.
11	Between Capes St. Mary and Vincent	Deep indigo	Very little matter, very pure.
12	Off the Burlings	Strong green	Thick, with fine matter.
13	Beyond the Burlings	Indigo	Very little matter, pure.
14	Off Cape Finisterre	Undecided	Less pure.
15	Bay of Biscay	Black-indigo	Very little matter, very pure.
16	Bay of Biscay	Indigo	Very fine matter. Iridescent.
17	Off Ushant	Dark green	A good deal of matter.
18	Off St. Catherine's	Yellow-green	Exceedingly thick.
19	Spithead	Green	Exceedingly thick.

thick with suspended matter, the second less thick, and the third still less thick. Thus the green brightened as the suspended matter diminished in amount.

"Previous to the fourth observation our excellent navigating lieutenant, Mr. Brown, steered along the coast, thus avoiding the adverse current which sets in, through the Strait, from the Atlantic to the Mediterranean. He was at length forced to cross the boundary of the Atlantic current, which was defined with extraordinary sharpness. On the one side of it the water was a vivid green, on the other a deep blue. Standing at the bow of the ship, a bottle could be filled with blue water, while at the same moment a bottle cast from the stern could be filled with green water. Two bottles were secured, one on each side of this remarkable boundary. In the distance the Atlantic had the hue called ultramarine; but looked fairly down upon, it was of almost inky blackness—black qualified by a trace of indigo.

"What change does the home examination here reveal? In passing the indigo, the water becomes suddenly augmented in purity, the suspended matter becoming suddenly less. Off Tarifa, the deep indigo disappears, and the sea is undecided in color. Accompanying this change, we have a rise in the quantity of suspended matter. Beyond Tarifa, we change to cobalt-blue, the suspended matter falling at the same time in quantity. This water is distinctly purer than the green. We approach Cadiz, and at twenty miles from the city get into yellow-green water; this the London examination shows to be thick with suspended matter. The same is true at Cadiz Harbor, and also of a point fourteen miles from Cadiz in the homeward direction. Here there is a sudden change from yellow-green to a bright emerald-green, and accompanying the change a sudden fall in the quantity of suspended matter. Between Cape St. Mary and Cape St. Vincent the water changes to the deepest indigo, a further diminution of the suspended matter being the concomitant phenomenon.

"We now reach the remarkable group of rocks called the Burlings, and find the water between the shore and the rocks a strong green; the home examination shows it to be thick with fine matter. Fifteen or twenty miles beyond the Burlings we come again into indigo water, from which the suspended matter has in great part disappeared. Off Cape Finisterre, about the place where the *Captain* went down, the water becomes green, and the home examination pronounces it to be thicker. Then we enter the Bay of Biscay, where the indigo resumes its power, and where the home examination shows the greatly augmented purity of the water. A second specimen of water, taken from the Bay of Biscay, held in suspension fine particles of a peculiar kind; the size of them was such as to render the water richly iridescent. It showed itself green, blue or salmon-colored, according to the direction of the line of vision. Finally, we come to our last two bottles, the one taken opposite St. Catherine's lighthouse, in the Isle of Wight, the other at Spithead. The sea at both these places was green, and both specimens, as might be expected, were pronounced by the home examination to be thick with suspended matter.

"Two distinct series of observations are here referred to—the one consisting of direct observations of the color of the sea, conducted during the voyage from Gibraltar to Portsmouth, the other

carried out in the laboratory of the Royal Institution. And here it is to be noted that in the home examination I never knew what water was placed in my hands. The labels, with the names of the localities written upon them, had been tied up, all information regarding the source of the water being thus held back. The bottles were simply numbered, and not till all of them had been examined, and described, were the labels opened, and the locality and sea-color corresponding to the various specimens ascertained. The home observations, therefore, must have been perfectly unbiased, and they clearly establish the association of the green color with fine suspended matter, and of the ultramarine color, and more especially of the black-indigo hue of the Atlantic, with the comparative absence of such matter.

"So much for mere observation; but what is the cause of the dark hue of the deep ocean? A preliminary remark or two will clear our way toward an explanation. Color resides in white light, appearing when any constituent of the white light is withdrawn. The hue of a purple liquid, for example, is immediately accounted for by its action on a spectrum. It cuts out the yellow and green, and allows the red and blue to pass through. The blending of these two colors produces the purple. But while such a liquid attacks with special energy the yellow and green, it enfeebles the whole spectrum. By increasing the thickness of the stratum we may absorb the whole of the light. The color of a blue liquid is similarly accounted for. It first extinguishes the red; then, as the thickness augments, it attacks the orange, yellow, and green in succession; the blue alone finally remaining. But even it might be extinguished by a sufficient depth of the liquid.

"And now we are prepared for a brief, but tolerably complete, statement of that action of sea-water upon light to which it owes its darkness. The spectrum embraces three classes of rays—the thermal, the visual and the chemical. These divisions overlap each other; the thermal rays are in part visual, the visual rays in part chemical and vice-versa. The vast body of thermal rays lies beyond the red, being invisible. These rays are attacked with exceeding energy by water. They are absorbed close to the surface of the sea, and are the great agents in evaporation. At the same time the whole spectrum suffers enfeeblement; water attacks all its rays, but with different degrees of energy. Of the visual rays, the red are first extinguished. As the solar beam

plunges deeper into the sea, orange follows red, yellow follows orange, green follows yellow and the various shades of blue, where the water is deep enough, follow green. Absolute extinction of the solar beam would be the consequence if the water were deep and uniform. If it contained no suspended matter, such water would be as black as ink. A reflected glimmer of ordinary light would reach us from its surface, as it would from the surface of actual ink; but no light, hence no color, would reach us from the body of the water. In very clear and deep sea-water this condition is approximately fulfilled, and hence the extraordinary darkness of such water. The indigo, already referred to, is, I believe, to be ascribed in part to the suspended matter, which is never absent, even in the purest natural water; and in part to the slight reflection of the light from the limiting surfaces of strata of different densities. A modification of light is thus thrown back to the eye, before the depth necessary to absolute extinction has been attained. An effect precisely similar occurs under the moraines of glaciers. The ice here is exceptionally compact, and, owing to the absence of the internal scattering common in bubbled ice, the light plunges into the mass, where it is extinguished, the perfectly clear ice presenting an appearance of pitchy blackness.[2]

"The green color of the sea has now to be accounted for; and here, again, let us fall back upon the sure basis of experiment. A strong white dinner-plate had a lead weight securely fastened to it. Fifty or sixty yards of strong hempen line were attached to the plate. My assistant, Thorgood, occupied a boat, fastened as usual to the davits of the *Urgent*, while I occupied a second boat nearer the stern of the ship. He cast the plate as a mariner heaves the lead, and by the time it reached me it had sunk a considerable depth in the water. In all cases the hue of this plate was green. Even when the sea was of the darkest indigo, the green was vivid and pronounced. I could notice the gradual deepening of the color as the plate sank, but at its greatest depth, even in indigo water, the color was still green.[3]

"Other observations confirmed this one. The *Urgent* is a screw steamer, and right over the blades of the screw was an orifice called the screw-well, through which one could look from

[2] I learn from a correspondent that certain Welsh tarns, which are reputed bottomless, have this inky hue.

[3] In no case, of course, is the green pure, but a mixture of green and blue.

the poop down upon the screw. The surface-glimmer, which so pesters the eye, was here in a great measure removed. Midway down, a plank crossed the screw-well from side to side; on this I placed myself and observed the action of the screw underneath. The eye was rendered sensitive by the moderation of the light; and, to remove still further all disturbing causes, Lieutenant Walton had a sail and tarpaulin thrown over the mouth of the well. Underneath this I perched myself on the plank and watched the screw. In an indigo sea the play of color was indescribably beautiful, and the contrast between the water, which had the screw blades, and that which had the bottom of the ocean, as a background, was extraordinary. The one was of the most brilliant green, and the other of the deepest ultramarine. The surface of the water above the screw-blade was always ruffled. Liquid lenses were thus formed, by which the light was withdrawn from some places and concentrated upon others, the water flashing with metallic lustre. The screw-blades in this case played the part of the dinner-plate in the former case, and there were other instances of a similar kind. The white bellies of porpoises showed the green hue, varying in intensity as the creatures swung to and fro between the surface and the deeper water. Foam, at a certain depth below the surface, was also green. In a rough sea the light which penetrated the summit of a wave sometimes reached the eye, a beautiful green cap being thus placed upon the wave, even in indigo water.

"But how is this color to be connected with the suspended particles? Take the dinner-plate which showed so brilliant a green when thrown into indigo water. Suppose it to diminish in size, until it reaches an almost microscopic magnitude. It would still behave substantially as the larger plate, sending to the eye its modicum of green light. If the plate, instead of being a large coherent mass, were ground to powder sufficiently fine, and in this condition diffused through the clear sea-water, it would also send green to the eye. In fact, the suspended particles which the home examination reveals act in all essential particulars like the plate, or like the screw-blades, or like the foam, or like the bellies of the porpoises. Thus I think the greenness of the sea is physically connected with the matter which it holds in suspension. . . .

"At some distance below the Whirlpool Rapids we have the celebrated whirlpool itself. Here the river makes a sudden bend

to the northeast, forming nearly a right angle with its previous direction. The water strikes the concave bank with great force, and scoops it incessantly away. A vast basin has been thus formed, in which the sweep of the river prolongs itself in gyratory currents. Bodies and trees which have come over the falls are stated to circulate here for days without finding the outlet. From various points of the cliffs above this is curiously hidden. The rush of the river into the whirlpool is obvious enough; and though you can imagine the outlet must be visible if one existed, you cannot find it. Turning, however, round the bend of the precipice to the northeast, the outlet comes to view.

"The Niagara season was over; the chatter of sight-seers had ceased, and the scene presented itself as one of holy seclusion and beauty. I went down to the river's edge, where the weird loneliness seemed to increase. The basin is enclosed by high and almost precipitous banks—covered, at the time, with russet woods. A kind of mystery attaches itself to gyrating water, due perhaps to the fact that we are to some extent ignorant of the direction of its force. It is said that, at certain points of the whirlpool, pine-trees are sucked down, to be ejected mysteriously elsewhere. The water is of the brightest emerald-green. The gorge through which it escapes is narrow, and the motion of the river swift though silent. The surface is steeply inclined, but it is perfectly unbroken. There are no lateral waves, no ripples with their breaking bubbles to raise a murmur, while the depth is here too great to allow the inequality of the bed to ruffle the surface. Nothing can be more beautiful than this sloping liquid mirror formed by the Niagara in sliding from the whirlpool.

"The green color is, I think, correctly accounted for in the last Fragment. While crossing the Atlantic, in 1872–1873, I had frequent opportunities of testing the explanation there given. Looked properly down upon, there are portions of the ocean to which we should hardly ascribe a trace of blue; at the most, a mere hint of indigo reaches the eye. The water, indeed, is practically black, and this is an indication both of its depth and of its freedom from mechanically suspended matter. In small thicknesses water is sensibly transparent to all kinds of light; but, as the thickness increases the rays of low refrangibility are first absorbed, and after them the other rays. Where, therefore, the water is very deep and very pure, all the colors are absorbed, and

such water ought to appear black, as no light is sent from its interior to the eye. The approximation of the Atlantic Ocean to this condition is an indication of its extreme purity.

"Throw a white pebble into such water; as it sinks it becomes greener and greener, and before it disappears, it reaches a vivid blue-green. Break such a pebble into fragments, each of these will behave like the unbroken mass; grind the pebble to powder, every particle will yield its modicum of green; and if the particles be so fine as to remain suspended in the water, the scattered light will be a uniform green. Hence the greenness of shoal water. You go to bed with the black Atlantic around you. You rise in the morning, find it a vivid green, and correctly infer that you are crossing the bank of Newfoundland. Such water is found charged with fine matter in a state of mechanical suspension. The light from the bottom may sometimes cross into play, but it is not necessary. A storm can render the water muddy, by rendering the particles too numerous and gross. Such a case occurred toward the close of my visit to Niagara. There had been rain and storm in the upper lake-regions, and the quantity of suspended matter brought down quite extinguished the fascinating green of the Horseshoe.

"Nothing can be more superb than the green of the Atlantic waves, when the circumstances are favorable to the exhibition of the color. As long as a wave remains unbroken no color appears; but when the foam just doubles over the crest, like an Alpine snow-cornice, under the cornice we often see a display of the most exquisite green. It is metallic in its brilliancy. But the foam is necessary to its production. The foam is first illuminated, and it scatters the light in all directions; the light which passes through the higher portion of the wave alone reaches the eye, and gives to that portion its matchless color. The folding of the wave, producing as it does a series of longitudinal protuberances and furrows which act like cylindrical lenses, introduces variation in the intensity of the light and materially enhances its beauty."

The question of the color of the Mediterranean and of other waters has been studied with a good deal of care by Aitken, whose work seems not to have received the attention which it deserves. Only a lengthy abstract of his paper is available and I quote from that.[4]

[4] Aitken: Proc. Roy. Soc. Edin. 11, 472 (1882).

"The experiments were made with a special view of determining whether the selective reflection or the selective absorption theory gave the correct explanation of the blueness seen in water. According to the selective reflection theory the color is due to the light reflected by extremely small particles of matter suspended in the water, these particles being so small they can reflect only the short waves of light, or those which belong to the blue end of the spectrum. The other theory explains the color by supposing that water has a selective absorption for the rays of the red end of the spectrum—that water is in fact a blue transparent medium. Three different methods were adopted of testing the correctness of these rival theories, and all three proved the water of the Mediterranean to be blue by selective absorption, and show that light in passing through the water has the rays of the red end of the spectrum absorbed, and only those of the blue end transmitted. The first method tried was to find out what is the color of the illumination of submerged objects. This was done by taking a long metal tube, closed at the end with a glass plate, sinking it vertically in the water, and looking through it at white and different colored objects fixed near the end of the tube. When this was done, it was found that a white object appeared of a most beautiful deep and delicate blue at a depth of 6 m. If the selective reflection theory was true, submerged objects would be illuminated with a color complementary to that reflected by the fine particles, and would therefore appear orange or yellow, the exact color depending on the amount of green in the reflected blue. If the blue color of the sky, as generally supposed, is due to the reflection of the blue rays by small particles of matter suspended in the air, it obviously follows that light in passing through our atmosphere must become of a color complementary to the blue of the sky; and it is asked, may not this be one of the reasons why the sun near the horizon, and all artificial lights when seen at a great distance, appear more or less yellow?

"The second method of experimenting was by looking at a white surface through a considerable length of water contained in a blackened tube. The light transmitted was found to be blue, thus showing the water to have a selective absorption for the rays of the red end of the spectrum.

"The third method was by sinking white and different colored

surfaces under water, and noting the change which took place in the colors. The colors selected were red, yellow, and purple. It was found that these colors when seen through the water changed in the same way as when seen through a blue transparent medium, such as a piece of glass. The white changed to blue. The red darkened very rapidly as it descended, a very small depth of water being sufficient to destroy all the color. At a depth of about 2 m. a very brilliant red was so darkened as to appear a dark brick red. Yellow changed to green by the water absorbing the red component of the yellow. An orange, as it sunk in the water, appeared to become more and more unripe, while a lemon became quite green. The purple surface quickly changed to a dark blue or violet by the selective absorption of the water. These changes, being all due to the cutting out of the red component of the colors, showed the water to have a selective absorption for the rays of the red end of the spectrum. If the water had been colored blue by selective reflection, then those test colors would all have appeared deficient in blue when sunk in the water, as the fine particles would reflect and scatter the blue rays. Experiments are described which show that when these colors are sunk in water colored blue by reflection from small particles, white changes to yellow, while yellow simply deepens in color, and purple grows redder.

"All these different methods of experimenting show this water to be a blue transparent medium, and that it acts in the same way as a solution of a blue salt or as a blue tinted glass. It is then shown that this selective absorption theory is not enough to account for the different color phenomena seen in water. A piece of blue glass or a blue solution have but little color when viewed from the side on which the light is falling, and it seems certain that light will penetrate pure water till it is all absorbed, and the water will look dark and colorless. Something more, and that of great importance, is obviously necessary to explain the different color phenomena seen in different waters, and in the same water at different times.

"If the water of the Mediterranean, when brilliantly colored, is examined by means of a concentrated beam of light, it is found to be full of fine solid particles in suspension. It is shown that it is to this dust of the sea—so to speak—that the Mediterranean owes its fine and varied coloring. The particles of this aquatic

dust are large, and reflect not only the blue rays, like the supposed particles of the selective reflection theory, but they reflect rays of all colors, and the water, by its selective absorption, strikes down the red rays, and only the blue rays are reflected to the surface and to the eye. These solid particles determine the brilliancy, and the selective absorption of the water determines its color. The color and the amount of the suspended particles is then considered. It is shown that the color of the particles will have a marked influence in the appearance of the water. If the particles are yellow—sand particles, for instance—then a blue colored water will appear to be green, as the light reflected by the yellow particles is deficient in the rays of the violet end of the spectrum.

"In the Mediterranean the solid particles are whitish, and all the different color phenomena are easily explained by the different amounts of the reflecting particles at the different places. Where the color is deep blue there are few particles in the water, and but little light reflected; and, further, the light passes through a great amount of water, and undergoes a great amount of selective absorption before it is reflected to the surface and to the eye. But if there are many particles in the water much light is reflected, and the color is chalky blue-green, as the light does not pass through so great a depth of water, and is therefore not so deeply colored, nor has it so many of the green rays cut out as in the water where the particles are few and far separated.

"Color experiments on a small scale with a solution of Prussian blue and a fine white powder are described. If the solution of Prussian blue is placed in a vessel, the bottom and sides of which are dark and reflect no light, then the colored solution appears dark and colorless; but if a little of the white powder is added then the solution at once becomes brilliantly colored. By varying the amount of the powder in the water all the varied color effects of the Mediterranean can be reproduced, a little powder causing the solution to appear deep blue, and as more powder is added the brilliancy of the water increases, and its color changes from blue to chalky blue-green.

"The presence and the abundance of white reflecting particles is shown to be a characteristic of all finely colored waters, and the wave-washed shores of the Mediterranean are shown to be the factories in which are prepared its reflecting particles. The waves, as they beat on the shore, grind up the stones and rocks,

and stir up a great amount of fine whitish solid matter, which gives the water along the shore a milky appearance.

"With the assistance of these whitish particles, we understand how it is that the brilliant blue-green of this sea depends so much on the continuance of sea-breezes. The longer the wave-mills have been at work the more fine powder has been produced along the shore, and more time given for the particles to be carried seaward, by the wave-mixed and wind-driven waters, and the blue-green which only extended in a narrow band along the shore, when the wind began to blow, is, after a few days of inshore wind, seen to extend far to sea. We also understand how it is that the color near shore is so brilliant and so much greener than outside. Near the shore there is a greater quantity of white solid matter in suspension; there is therefore more light reflected, and further, the light does not penetrate through so great a depth of water, and has not so much of the light of the red end of the spectrum cut out, and therefore looks greener than the water outside, the light from which has to penetrate a greater depth of the absorbing medium. The blueness and beauty of the Mediterranean would thus appear to be due to the blue transparency of its waters, coupled with the presence of white reflecting particles, and the variety in its coloring to the amount of the suspended particles at different places and at different times.

"From this we see the important influence which the geological formation of the shore has on the appearance of the water of a sea, as it determines the nature of the solid suspended particles. This is beautifully illustrated by the difference of coloring in the Mediterranean at Mentone and at Cannes. At Mentone, limestone is everywhere abundant along the shore, and this limestone, when ground up by the waves, produces an extremely fine and white powder, which mixed with the water, causes the sea at Mentone to be far more brilliantly colored than it is at Cannes, where there is but little limestone, and the shore is almost everywhere covered with sand, the débris of the surrounding rocks.

"In the experiments in the Mediterranean it was found that the solid particles were so abundant that they prevented the sun's rays penetrating in a direct line to any great depth. This was shown by the illumination of the white surface placed at some distance under the water, and seen through the empty tube, being the same, whether the surface was turned towards the sun or away

from it. It was also shown by the fact that at a depth of 6 m. these solid particles were found to reflect about as much light as a white surface did. These solid particles act like a fog, and, while they stop the light penetrating in a direct line, yet allow it to penetrate much further by internal reflection. The sun's rays get entangled—so to speak—among the particles, and are reflected from particle to particle, becoming a deeper blue with each reflection, so that the particles become illuminated with blue light. From this it is obvious that the more transparent the water, and the greater the reflecting power of the particles, the more deeply colored will the water appear.

"The Lake of Como was the next water visited. A white surface seen through its waters showed it to be as deeply colored as the Mediterranean, yet the absence of white reflecting particles in its waters and its dark-colored bottom, cause it to appear comparatively dark and colorless. When a quantity of white reflecting particles are artificially mixed up with the water in this lake a fine blue-green cloud was formed, which remained visible for some time amidst the darker waters, and showed that all this lake required to make it brilliantly colored was the presence of white suspended particles in its waters. The waters of Como, in their passage from the lake to form the river Adda, change to a fine blue. This sudden alteration in the appearance of the water is shown to be probably due to the addition of fine reflecting particles to the water on entering the river. Lago Maggiore, compared with Como and the Mediterranean, looks greener than either, but reflects more light than Como.

"The Lake of Geneva, whose waters have been so highly praised by all writers, was next visited, and the explanation given of the coloring of the Mediterranean was found to apply here also. Near Bouveret, where the Rhone enters the lake, all the variety of color phenomena seen in the Mediterranean were repeated. The light colored muddy waters of the entering river, as they stretched far into the lake, represented the whitish waters near shore in the Mediterranean, and where this whitish stream mixed with the waters of the lake, the bright blue-green of the Mediterranean was reproduced, while further out the waters were deeper blue, rivalling in brilliancy those of the Mediterranean. The work done by the waves along the shores of the Mediterranean in manufacturing the light-reflecting particles, is for the Lake of Geneva, done by the

grinding of the glacier mills and streams of the Rhone valley.

"The silt brought down by the Rhone was found to be composed of clean white particles, like fine white sand. Many of the particles are thin polished plates, and when examined by means of a concentrated beam of light, while in suspension in water, are seen to flash brilliantly in the strong light. This white solid matter brought down by the Rhone is constantly being deposited all over the bottom of the lake, and it is this whitish deposit which gives to the Lake of Geneva one of its peculiarities. The light reflected from the whitish bottom causes the water of the lake, all along the shore to appear of a peculiar light blue-green color, and enables us to judge of the depth of the lake at depths far beyond that to which we can see the bottom. We can only see a white surface of 15 cm. square to a depth of about 7 m., yet the light reflected from the bottom affects the appearance of the water at depths far beyond 7 m., showing that light penetrates by diffusion in these waters to far greater depths than it can directly. The brilliancy and beauty of the Lake of Geneva would thus appear to be due to the purity and transparency of its waters, coupled with the presence of an enormous amount of white reflecting surfaces, both in suspension in its water and deposited all over the bottom of the lake, the effect being intensified by the brilliancy of the reflecting particles.

"The color of the water in Lake Bourget was found to be similar to that in the Lake of Geneva, though at the time it was visited it was slightly more turbid. A white surface could not be seen to so great a depth as in Geneva, and the water, even in the middle of the lake, when examined by means of a concentrated beam of sunlight was found to be very full of suspended light-reflecting particles similar to those brought down by the Rhone. The examination of the water in these lakes was confined to the colored surface experiments, and to a spectroscopic examination of the internally reflected light. The results were all similar to those in the Mediterranean.

"In the beginning of autumn the sea off the west coast of Scotland, near the village of Ballantree, and also in Brodick Bay, was visited, and the water examined by means of submerged colored surfaces, and by means of the spectroscope. The water was here found to be much greener than any previously examined. A large quantity of this water was filtered, when it was found

that most of the suspended particles were fine grains of sand. From this it is concluded that the greenness of our northern seas is in part due to the reflecting particles being yellow, and the reflected light, therefore, deficient in the more refrangible rays. These yellow sand particles not only explain part of the greenness of our northern seas, but they also explain their comparative darkness and deadness, the yellow sand particles reflecting so little light. The importance, however, of even these bad reflectors was very evident during the time the observations were being made. It was noticed that the water was much more brilliantly green during and immediately after an inshore wind, and when the filter showed the water to have a good deal of sand in suspension, than after a calm, when many of the particles had settled out. Some water collected about a mile seaward from Ballantrae was examined in a glass tube 7½ m. long, and was found to be of a blue-green color.

"The water of Loch Lomond was next examined, and found to be a perfect contrast to any previously described, being of a color nearly complementary to that of the Lake of Geneva. A white surface seen through its waters appeared yellow, and the submerged colored surafces showed its waters to have their greatest absorption for the rays of the violet end of the spectrum. Its waters reflect a slightly yellowish light, its spectrum being brightest in the yellow. This water is so deficient in reflecting particles that its brightness is never greater than what we call brown. If it was supplied with abundant reflecting particles Loch Lomond would be a yellow lake.

"Well waters were also examined for color by placing them in long tubes, and looking through the water at white and at colored surfaces. The tubes were in pieces, so that they could be fitted up in lengths of from 3 m. to 15 m., to suit the transparency of the water under examination. The tubes were fixed horizontally, and at a convenient height for looking through them, and the water to be tested was poured in till the tube was half full, so that by looking through the upper half of the tube the colored surface could be seen, and through the lower half the effect of the absorption of the water on the color, and on the brilliancy, of the transmitted light. The transmitted light was also examined by means of a spectroscope.

"The colors of the different waters were found to vary

greatly. One sample was of a fine blue, others were green-blue, some green, whilst others were of colors between green and yellow, but all were of colors between blue and yellow. It was observed that the more transparent a water was, the nearer its color was to blue. Scarcely any light could be seen through 7 m. of any of the yellowish waters, whilst through this length all the bluish waters were quite transparent, and the spectroscope showed that some of the waters transmitted almost the entire light of the blue end of the spectrum, and only stopped the rays at the red end. When one of the bluish waters was examined in a tube 15 m., or nearly 50 feet long, it appeared of a fine blue-green as transparent as a piece of glass.

"Only a very little relation could be traced between the color of a water—when tested in long tubes—and its suitability for dietetic purposes.

"The *cause* of the color of water has been a frequent subject of speculation. Every substance which has been discovered in water has in turn been suggested as the cause of the color. When no useful purpose could be given for its presence, it was told off to do the ornamental, and make the water beautiful to the eye. All these speculations assume that the color is due to some impurity in the water. This, however, is obviously begging the question. It is first necessary to find out whether water has any color in itself, and what that color is, before we can say anything about the effect of impurities. As it would be impossible to prepare absolutely pure water, and as we might still be in doubt as to whether any color seen in purified water was due to the water or to the impurities, the following method of experimenting was adopted: Distilled water was prepared in two sets of apparatus; in one set the condensing tube, the collecting bottle, and the testing tube were all of glass; in the other set they were all made of brass. If the waters prepared in these two sets of apparatus have the same color, then the probability is that the color is due to the water, as the impurities will be different in the two samples, and they would probably give different colors. The result was, the color of the samples of water prepared in both sets of apparatus was the same—namely, blue. This conclusion was further confirmed by preparing another sample of the water, and condensing it this time in a platinum tube. The water so prepared was also found to be of a fine blue. All three samples were almost exactly

the same color as Prussian blue. Standards of color were kept with which the different samples of water were compared, both for the color and for the amount of the color. As all the different samples of distilled water—after the apparatus was thoroughly purified—had the same color and amount of color, it seems almost certain that water is a blue transparent substance, and that the color in these experiments could not be due to impurities, which must have varied both in kind and in amount in the different samples of water. Further, as the amount of color in the Mediterranean water, and in the bluish well waters, was as near as could be judged the same as in pure waters, it does not seem necessary to call in the aid of impurities to account for the blue color seen in the lakes and seas, the color being principally due to the water itself, and the different substances in solution, instead of making the water blue, tend to change its proper color and make it green or yellow.

"The addition of impurities to water seems generally to change its color from blue to green, or to yellow, though there seems to be no reason why some impurity may not change it to a deeper blue. The selective-absorption of the water remains the same, while the impurities add their selective-absorption to that of the water, and while they change the color they also decrease its transparency. This explains why it is that the yellow well waters are so much less transparent than the blue. This must necessarily be so, as a very small depth of water destroys the rays which give yellow, and the transparency of yellow waters can only be the transparency of water for yellow light, which is very much less than for blue light. No attempt was made to find out what the different discoloring substances in water are. The task would evidently be an endless one, and of little value.

"The effect of the light reflected from the surface of the water is then referred to. It is shown that when the sky is covered with white clouds, the surface reflection is so strong as to mask the color of the water, and that when the sky is deep blue the sky-reflected light intensifies and deepens the apparent color of the water. The importance of the surface-reflected light is best seen when the sky is covered with clouds, and glowing with a color different from that of the water, as at sunset when the clouds are richly colored all over the sky and deeply down towards the horizon. The water will then, especially if calm, appear like

a sea of molten metal glowing with sky-reflected light, so powerful and brilliant as entirely to overpower the light internally reflected by the water.

"Pure water having been shown to be perfectly transparent to the more refrangible rays, and as it absorbs the red rays, water, when looked at from the side on which the light is falling, must necessarily be dark, and cannot reflect any perceptible amount of blue light. We must, therefore, look to the solid particles in suspension in the water as the cause of the light reflected by water, and while the selective absorption of the water principally determines its color, its brilliancy is entirely determined by the suspended particles. It is shown why it is that though we have waters of many colors, yet we only observe the color when it is blue or green, and never when it is yellow. Amongst other reasons given is the much less brilliancy of yellow waters, this less brilliancy being due to the less transparency of the yellow waters compared to blue; only the reflecting particles near the surface are active in the yellow water, whereas the particles to a considerable depth in the blue can reflect their light to the surface. This is one reason why Loch Lomond is so much darker than the Lake of Geneva. Loch Lomond certainly has fewer and less powerful reflecting particles than the Lake of Geneva, but it is darker also, because only the particles to a much less depth can reflect their light to the surface.

"The waters of our northern seas, when provided with proper reflecting particles, such as air-bells and white particles, are shown to be much bluer than they generally appear. The brightness and blueness of the waters off the coast of Cornwall are shown to be due to the beaches along this coast being at many points covered with a whitish-colored sand, which gets mixed up with the water by the action of the waves. As the water of the sea is constantly circulating, it seems impossible that the same water can be one color at one place, and a different color at another, but we can easily see how the different colors and degrees of brilliancy can be produced by the color and the amount of suspended matter at the different places—where the water is mixed with whitish particles being bluish, and where mixed with yellow particles appearing greener—whilst its brilliancy is determined by the amount of suspended particles which may be present at the time in the water.

"In conclusion, a lake in the Cordilleras is referred to as combining all the conditions necessary for producing fine and brilliantly blue colored waters. The traveller in describing this lake says: 'Its waters were of the most extraordinarily brilliant blue I ever beheld.' From the description, this lake is in many respects like the Lake of Geneva. It is provided with an abundant supply of pure glacier water, free from discoloring impurities, but laden with abundance of white-reflecting particles, whose presence is evidenced by a 'white strip' around the lake."

In a letter to Professor Tait, dated Mentone, April 14, 1882, Aitken[5] says:

"Since coming here this time I have tested the sea with the polariscope and with the spectroscope. With an instrument by Hoffman, which gives colored bands with polarized light, I have been able to detect small, but decided indications of polarization in the light internally reflected by the water, the surface reflection being, of course, cut off when the observation was made. At present I think the polarization is due to regular reflection from the polished surfaces of some of the particles, which are seen to glance brightly in concentrated sunlight.

"I have also detected an absorption band in the green of the spectrum of the light internally reflected by the Mediterranean water. This band is much more distinct in water where there are but few reflecting particles, and the light undergoes a great amount of selective absorption. At about a mile from shore, where I could see a white surface 6 inches square at a depth of 16 metres, the absorption band was quite distinct, but became less and less as I approached the shore, where there was more matter in suspension and the water less transparent, but the spectrum more brilliant. I cannot say whether this band belongs to water or to salt, or to what it is due, never having noticed it before; but I never examined water so transparent, and where the light had undergone so much absorption."

Subsequently to Aitken, but apparently independently, Spring[6] made a thorough and interesting study of the color of water. "Water in large masses always appears colored to us; but the color is not always the same and the tints are rich and vary enormously. The Mediterranean is the most beautiful indigo;

[5] Aitken: Proc. Roy. Soc. Edin. **11**, 472 (1882).
[6] Bull. Acad. roy. belg., (3) **5**, 55 (1883).

the Atlantic is sky-blue; the Lake of Geneva is famous for the beauty of transparency of its azure waters; the Lake of Constance, the Rhine which flows from it, the Lake of Zürich and the Lake of Lucerne are just as transparent, but the waters are more green than blue. The little Kloenthaler Sea near Glaris can scarcely be distinguished from the surrounding fields, the water is so near the color of the grass on the banks. Among the more deeply colored waters I will mention only the Lake of Staffel near Murnau at the foot of the Bavarian Alps. On the day that I saw it, the water seemed absolutely black, although perfectly clear when seen in thin layers."

(To be concluded.)

A New Alloy. ANON. (*American Machinist,* vol. 1, No. 8, February 20, 1919, p. 374.)—Because of the high temperature required for suitably hardening tools of tungsten high-speed steel Sheffield toolmakers have sought a substitute metal.

A new alloy produced by adding cobalt to chromium-carbon steel is reported to be best hardened by a temperature of 1200° C. For most purposes the hardening required is obtained when the tool is cooled naturally in draft-free air. In a comparative test saws of "cobalt-crom," as the new steel is called, continued cutting for four days, it is stated without regrinding, while saws of tungsten high-speed steel were dulled in two days and those of carbon steel in half a day.

Bibliography of Screw Threads. H. E. HAFERKORN. (*Professional Memoirs Engineer School,* Washington Barracks, vol. x, No. 54, November-December, 1918, Supplement No. 2.)—The aim of this bibliography is to furnish accounts, as complete as possible, of the various domestic and foreign forms and systems of screw threads together with professional reports relating to actual experience and study. In all, 379 titles are recorded. The value of a list which brings within reach many scattered monographs on this important subject is obvious. An index to authors, titles, subjects and topics is included.

Relation of Dehydration to Agriculture. G. C. PRESCOTT. (*U. S. Dept. of Agriculture, Circular 126,* January 25, 1919.)—Drying has been known for hundreds of years and is probably the oldest method of food preservation which the human race has employed. In this country it was used in the early colonial days for both animal and vegetable foods. Massachusetts colonists dried corn after it had been cooked, the product being known as samp. Fruits, and especially the apple, were also dried in considerable quantities. Along the coast, the drying of fish became an important industry. In other parts of the country, other vegetables and fruits and meat products were dried. Peas and sweet corn may be mentioned as examples of the former, while along the Pacific coast, the long sunny period lends itself particularly to the drying of prunes, raisins and other fruits. In the arid regions of the interior, the Indians, and later the early settlers, dried their beef or buffalo meat by cutting into thin strips and hanging up for sun and wind to remove the excess moisture and sear over the outside with a protective coating which would prevent infection and spoilage. This was known as jerked beef.

The advantages of dehydration are almost too obvious to require extended statement. Most evident of all is the loss in weight. Vegetables in common use contain from 60 to 95 per cent. of water. The dehydrated product should contain from 5 to 10 per cent. of water. There is therefore a very large reduction in weight and consequent saving in transportation charges, which are in general based upon weight. Similarly there is a loss in bulk amounting from 50 to 80 per cent. of the bulk of the raw material. From the standpoint of agriculture, the greatest advantage of dehydration is in the stabilization of crops and the conservation of materials. With dehydration, the excess of the years of great yield can be stored up and made available in the following year when prices are higher and the crop much smaller. Another great advantage is in the conservation of food materials. It is estimated that over 50 per cent. of the fruits and vegetables grown in this country never reach the consumer as a result of poor transportation facilities, irregularities in marketing or other causes. A third factor of importance in relation of dehydration to agriculture lies in the better diversity of crops that can be secured, and as a result of this the greater variety available to poor and rich alike throughout the year.

VEHICULAR TUNNELS UNDER THE HUDSON RIVER.*

BY

MARTIN SCHREIBER, M.Am.Soc.C.E.,

Chief Engineer, Public Service Railway Co., Newark, New Jersey.

THE population of metropolitan New York, say within a radius of ten miles, is about 7,000,000 people. On Long Island, and in Brooklyn and Queens, which are separated from Manhattan by the East River, and in Richmond, there are 2,500,000 people. On the Island of Manhattan and the Bronx and to the north within this radius, the population is 3,000,000 people. On the New Jersey side of the Hudson River there are about 1,500,000 people.

The transportation needs for such a community present a tremendous problem. The problem is complicated by the fact that metropolitan New York is not only the great gateway of the country, but one of the great ports of the world. Here we have railroads, aggregating approximately 29,000 miles, terminating on the Jersey side of the Hudson. On the Manhattan side of the Hudson there are termini representing about 11,000 miles, making a complete termini in the metropolitan area of approximately 40,000 miles of railroad. Moreover, there are seventy-seven foreign steamship lines operating from the port to all parts of the globe. There are more manufacturers in this district than the combined number in Chicago, Philadelphia and St. Louis. In this metropolitan area, Long Island and Manhattan districts are tied together over the East River by a number of bridges. These are the Brooklyn, Manhattan, Williamsburg and Queensboro bridges, which are among the largest structures of their kind in the world. Crossing the East River on these bridges are tweny-six railroad tracks and four highway roads for vehicles, with fourteen additional tracks in tunnels.

In striking contrast to the facilities over the East River are those across the Hudson River connecting the New Jersey district with the remainder of the metropolitan area. Here there are only six railroad tracks operating through tunnels under the Hudson River, two by the Pennsylvania Railroad and four by the Hudson

* Presented at the Stated Meeting held Wednesday, December 18, 1918.

and Manhattan Railroad. There are no highways at all. So the remaining business, either vehicular or passenger, must be transported by means of ferryboats.

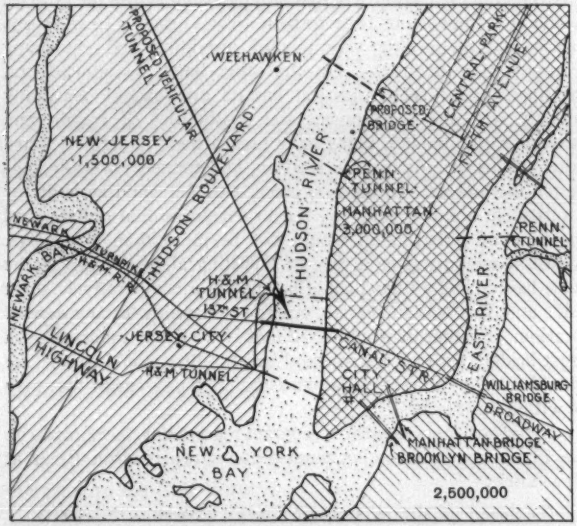
Even to the most casual observer it must be evident that the New Jersey side of the metropolitan district is at a great disadvantage when compared to the remainder of the area. Taking the steam railroads, for example, with seventy-three per cent. of all the mileage entering the Port of New York, or termini representing about 29,000 miles, stopping on the Jersey side of the Hudson with the major part of their business to be done on the opposite side of the river, certainly creates a condition which is not economically sound.

In the early days it was not such a serious problem to ferry the cars, vehicles and people across the river. But as the district developed, more ferries, more tugs, more car floats and more lighters had to be brought into play, and now with the increased maritime business the river is congested with watercraft. Present facilities are entirely inadequate to meet the growing demands of the community, even under favorable conditions. When the river is blanketed with fog or filled with ice, not an uncommon occurrence, the whole transportation scheme is thrown out of gear. The stranger has this strongly impressed upon him if he happens to drive over the Lincoln Highway to Jersey City, for before he can get on a Cortlandt Street or Desbrosses Street ferryboat, we will say, it will be necessary for him to run a blockade of trucks, automobiles and other vehicles that clog Montgomery Street, Jersey City, for several blocks.

A large portion of the food supply for 7,000,000 persons is brought to the piers on the west side of the Hudson by the railroads. Owing to the congested and generally inadequate terminal facilities there is wastage of perishable food products before distribution can be made.

The bridging of the Hudson River at New York is a question that has been before the people of the States of New York and New Jersey for at least thirty years. No doubt a bridge would have been constructed long ago if it had been possible to finance the proposition. Unfortunately, the first outlay for such a structure would be very great, as it would be necessary to build a bridge large enough to anticipate future as well as present needs. It would be very uneconomical to build two or more bridges,

when a little more money spent for a given bridge would double its carrying capacity. This is especially true of such a bridge as has been proposed for the Hudson River, with a span of almost 3000 feet, which must be of abnormal width and strength to even carry its own weight. An idea of the magnitude of a Hudson River bridge may be obtained when it is realized that the bridge



Map showing location of proposed vehicular tunnel.

proposed by Boller, Hodge & Baird, consulting engineers for the New York State Bridge and Tunnel Commission, to be built at Fifty-seventh Street, would have had a single span of almost twice the length of the Manhattan or Brooklyn Bridge spans. The plans called for a span longer than that of any bridge in the world. The proposed bridge was to be 170 feet clear above high water and its towers to support the suspension cables were to reach 600 feet above the water. The width of the bridge was fixed at 204 feet. Its proposed capacity was eight tracks for rapid transit

trains, two driveways (each thirty-six feet in width) and two eight-foot sidewalks. In 1913 the cost of the Fifty-seventh Street Bridge was estimated at $42,000,000. No doubt it would now cost nearly double that amount and it would take from six to ten years to construct it.

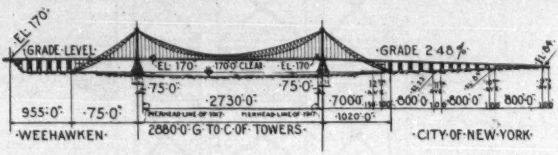
Any one who has given thought to the traffic situation in the metropolitan area would say that such a bridge across the Hudson would be a tremendous boon to both New York and New Jersey, and would go a long way toward providing and equalizing transportation facilities. On the other hand, as pointed out, the financing of such a project has its drawbacks. Naturally enough, with the development and possibilities of freight and passenger automobiles, many have turned their thoughts toward other means of crossing the Hudson, and tunnels naturally suggested themselves. In the first place, a tunnel could be built for a relatively nominal sum, say ten to fifteen million dollars, and the time of construction would not be more than two years. Again, it would not be a case of "putting all your eggs in the same basket," as a tunnel could be built in a comparatively short time, and, if it was successful, others could follow at any desired location. Further, it would seem that if we are not able to get a great bridge, with all the splendid benefits that would accrue, we should not deny ourselves any measure of improvement that may be within our reach.

In the last few years three separate reports have been made on the feasibility of vehicular tunnels under the Hudson River at New York:

(1) Report of Messrs. Jacobs & Davies, Consulting Engineers for the New Jersey Interstate Bridge and Tunnel Commission.
(2) Report of Special Committee on Vehicular Tunnel Project, to Public Service Corporation of New Jersey.
(3) Report of General G. W. Goethals for the Interstate Bridge and Tunnel Commissions of New York and of New Jersey.

All three reports agreed on the one location, which was first proposed by Messrs. Jacobs & Davies, and extends from Twelfth Street, Jersey City, to Canal Street, New York. The termini of the tunnel at both ends are located in the centre of the trucking and freight districts. The terminus on the Jersey side is not only in the midst of a busy industrial centre, but is also adjacent to

the great freight yards of the Erie, Pennsylvania and Lackawanna Railroads and close to the Christopher, Barclay, Desbrosses, Chambers and Cortlandt Street Ferries. The tunnel would be in direct line with the Newark and Jersey City Turnpike, the Belleville Turnpike and Lincoln Highway on the Jersey side of the Hudson; while on the New York side, it would be in direct communication with the Manhattan and Williamsburg bridges to Brooklyn and Long Island. So, it is seen that this location is particularly favorable with relation to main traffic arteries. Also, not far from the vicinity of the terminus on the Jersey side is one of the largest trans-Atlantic terminals in existence. On the New York side are the piers of numerous steamship companies, such as the New England Navigation Company operating to Fall River and Portland; the Central Hudson Steamboat Company



Proposed Hudson River bridge, near 57th Street. 2880' 0", center span; 4920' 0", between anchorages; 8330' 0", entire length from 9th Avenue to top of Palisades; maximum grade, 2.48 per cent. (*Boller, Hodge and Baird.*)

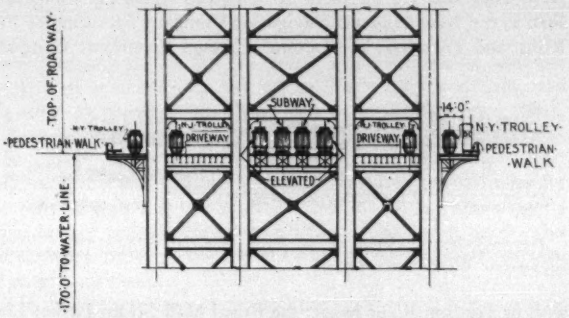
with its Hudson River boats; the Royal Mail Steam Packet Line to Bermuda and the West Indies, and the Southern Steamship Company to the Gulf Ports.

It was estimated by Mr. Percy Ingalls, of the Special Committee of Public Service Corporation of New Jersey, referred to heretofore, that by 1920 at least 4,000,000 vehicles a year will be crossing the five adjacent ferries and that at least 2,000,000 would use a tunnel if one were constructed. In this connection it is interesting to note that the Blackwall and Rotherhithe Tunnels under the Thames River, England, handle only about 1,000,000 vehicles each per annum.

When the unusually favorable location of the tunnel proposed is considered, it does not appear that there would be much of a risk involved in building at least a single tunnel between Twelfth Street, Jersey City, and Canal Street, New York. In addition to lending itself to vehicular business, such a tunnel could be

adapted to almost any scheme for the development of the transportation systems of the Port of New York.

So far as the methods of construction of the proposed vehicular tunnel are concerned, there are differences of opinion as to certain engineering features. The first and third reports, already referred to, recommend that the tunnel be driven by the well-known shield and compressed air method. This was the method used in constructing the present tunnels under the Hudson and East Rivers, and was also used for the existing tunnels under the Thames River, England. With this plan a shield chamber is sunk at one or both ends of the tunnel and the shield installed.

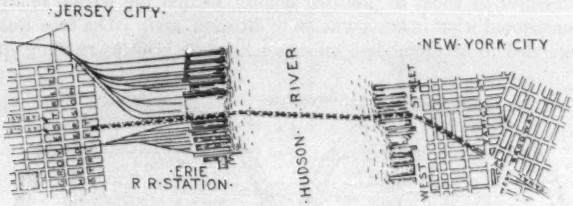


Sectional view of tower for proposed Hudson River bridge, near 57th Street.
(*Boller, Hodge and Baird.*)

For example, the shield in the case of the Pennsylvania Railroad tunnels across the Hudson at Thirty-fourth Street, as designed by Mr. Charles M. Jacobs, the consulting engineer, was about eighteen feet long and twenty-three feet in diameter, and made of three-quarter-inch plates which also formed the cutting edge. The shield was forced forward by twenty-four hydraulic jacks that exerted a pressure of 3400 tons. As the shield was moved ahead by displacement of the silt or mucking through doors in the bulkhead, it was followed up by the installation of a cast-iron sectional lining that was bolted together and caulked watertight.

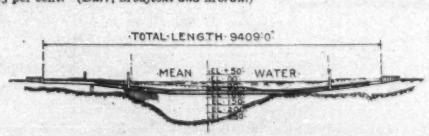
The first reports, recommending the usual shield-driven tunnel, included the customary iron lining. The third report, also recommending a shield-driven tunnel, included a special concrete

block lining. The shield-driven tunnel has the advantage of being not only well tried but may be carried out without disturbing the surface of the land or water along the route of the tunnel, except, say, at the approaches. Although the first and third reports recommended the shield-driven tunnel, they do not recommend the same cross-section. Jacobs & Davies' report proposes two single tubes approximately twenty-seven feet in diameter with seventeen foot roadways and a walk on each side. This arrangement would allow two lines of vehicles, one slow moving and one fast moving, in



PLAN.

Proposed vehicular tunnel between 12th Street, Jersey City, and Canal Street, New York City. Total length, 9409'.0"; length between bulkhead lines 5495'; length between pierhead lines 3724'; maximum grade New Jersey approach 4.55 per cent.; maximum grade New York approach 3.85 per cent. (*Burr, Modjeski and Moran.*)

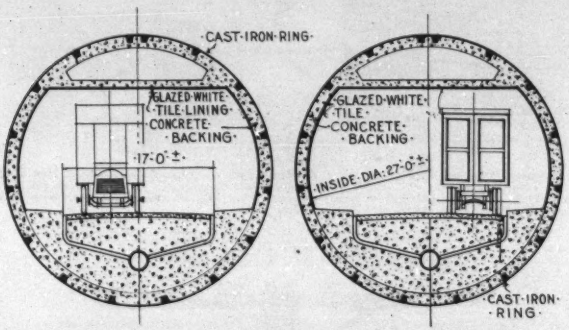


Profile. Maximum depth at low water 55' 0".

each tube; or four lines of vehicles in both tunnels. It also has an advantage in natural ventilation, as vehicles moving in the same direction have a tendency to exhaust the foul air that is replaced with a certain quantity of fresh air from the mouth of the tunnel.

Gen. Geo. W. Goethals advocates a shield-driven single tube, thirty-six feet in diameter, with two eighteen-foot roadways, one superimposed above the other and a concrete floor between them. Such a cross-section would also allow four lines of vehicles, two of the faster-moving type (such as pleasure automobiles) on the upper floor, and two of the slower-moving vehicles (such as automobile trucks) on the lower floor.

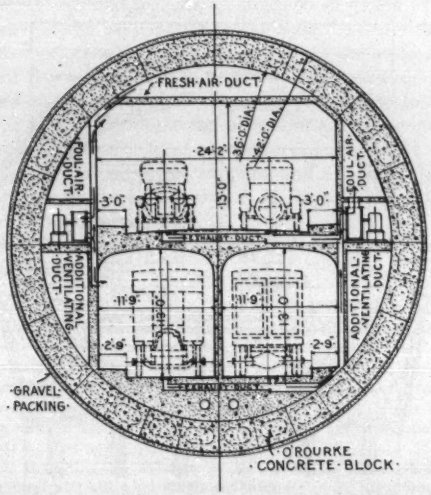
The second report, as proposed by Messrs. Wm. H. Burr, Ralph Modjeski and Daniel E. Moran, the board of engineers for Public Service Corporation of New Jersey, differed from the other two both in character of the cross-section of tunnel and in method of construction. This report proposes a single tube, having a seventeen-foot roadway, with an elliptical cross-section. The tunnel was to be of reinforced concrete and have a minimum thickness of four feet. It was to be an arch section and so designed as to sustain to the best advantage the varying pressures of water at different depths, so that the section really constituted what is known as an hydrostatic arch. The tube was intended to accommodate only two lines of vehicles running in



Cross section of proposed vehicular tunnels under Hudson River. (*Jacobs and Davies.*)

opposite directions. Its operation was to be similar to the Blackwall and Rotherhithe Tunnels under the Thames River. The maximum capacity of this tunnel was figured at 6,000,000 vehicles per year, two or three times as many as it was thought it would be called upon to accommodate for a long time. The entire length, from portal to portal, was 9409 feet, with 5495 feet between bulkhead lines. It was proposed to build the river section 2680 feet long, by excavating a trench so that the bottom of the same would be eighty feet below mean low water. The width of the trench at the bottom was to be forty feet and it was to be sloped off at an angle to the horizon of one to three. Piles were then to be driven in the trench on five-foot and eight-foot centres, and cut off at about seventy-eight feet below low water.

These piles were to form a foundation for the reinforced concrete tunnel. Each section of the tunnel, which was to be eighty feet long, was to be completed on launchways at convenient locations. After closing these sections with timber bulkheads and towing them to the tunnel site they are to be sunk in place. After the sections were joined together by specially designed joints the bulkheads were to be removed. This method of construction is



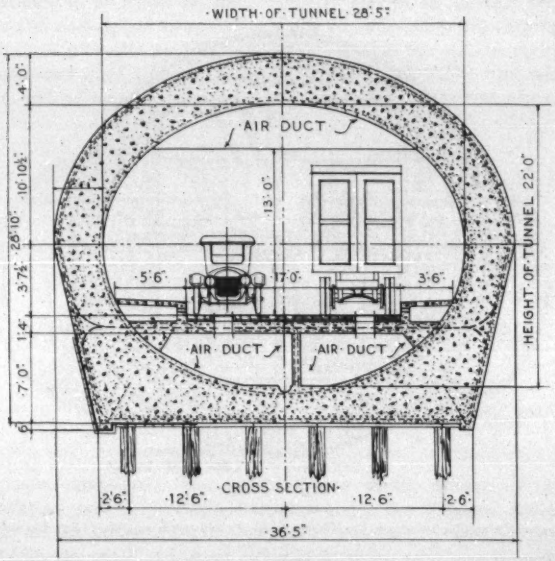
CROSS SECTION.

Proposed highway tunnel between Canal Street, New York, and 12th Street, Jersey City. (*Goethals.*)

not altogether new, as somewhat similar methods were used in connection with the Detroit River Tunnel and the tunnel across the Harlem River, New York.

The remaining portions of the tunnel, between the portals and the river sections on each side of the river, were to be constructed by the open or the pneumatic caisson method. The advantage claimed for the trench method of construction was economy and least depth below mean low water, which was figured for the first time by the Government at fifty feet.

In connection with the report of Public Service Corporation, the board of engineers made a special investigation of tunnel ventilation. Some engineers had doubted the practicability of operating a tunnel of the length proposed for motor vehicles on account of the danger of carbon-monoxide in the exhaust gases, although it had already been pointed out by Messrs. Jacobs & Davies in their report that mechanical ventilation was feasible.



Proposed highway tunnel between Canal Street, New York, and 12th Street, Jersey City. (*Burr, Modjeski and Moran.*)

Assuming that all other engineering problems, such as construction and drainage, could be overcome if it were impossible to remove or dilute the poisonous gases, it was evident that the entire project would have to be abandoned. Up to the time the preliminary study of the tunnel was undertaken very little information was available concerning waste from gas engines, although all other information (such as proper proportion of air to gas

for perfect combustion) was readily obtainable. Fatalities, due to exhaust gases in garages, are becoming quite common, and this may cause more interest in the general subject of exhaust gases in the near future.

In considering the ventilation of the tunnel, the number of cars that might be in the flume at any one time could be assumed; likewise the average horsepower per motor, the speed at which the car would run and the average mileage per gallon of gasoline. So it was quite an easy matter to calculate the quantity of fresh air necessary to take care of the operation of the motors. At the same time it was necessary to ascertain how much air should be exhausted and how much air supplied per minute to make the air livable and to overcome the poisonous carbon-monoxide.

Various authorities have advanced different ideas as to the proper quantity of air to be supplied and exhausted, and some have gone so far as to say that it is impossible to ventilate a tunnel of this kind at all.

Four different schemes were given consideration for the ventilation of the tunnel:

First: Utilizing the suction of cars running through the tunnel. This idea was abandoned when the neutralizing effect of cars running in opposite directions was considered.

Second: Forcing large quantities of air in one end of the tunnel and exhausting at the other. This was eliminated when it was considered that the total exhaust gases in the tunnel would be forced to one end and would probably make the air at that point quite dangerous.

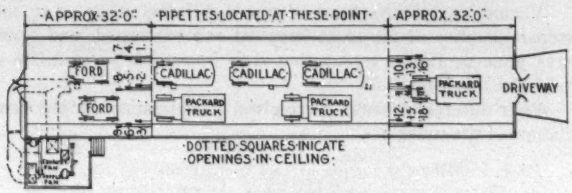
Third: Installing an exhaust system drawing all air from the tunnel and allowing fresh air to come in at the portals and through fresh air shafts which would be built at the bulkhead line on both shores of the river. This scheme was also considered impracticable when it was found that the condition would be similar to Scheme No. 2, except that considerable of the foul gases would be drawn to the centre of the tunnel, with very little fresh air to dilute them.

Fourth: To install a system of both supply and exhaust fans and ducts, with inlet and outlet openings at various points, so that the tunnel could be theoretically blocked off into sections, each section having its separate inlet and outlet opening. This plan was finally adopted.

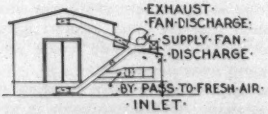
With Scheme No. 4 arose the same old question as to the proper quantity of air necessary for both supply and exhaust. As before

mentioned, little was known about the properties of exhaust gases, and, therefore, no stated quantities could be decided upon. For this reason the engineers decided to erect a test building of the same cross-sectional design and dimensions as the proposed tunnel and of sufficient length to enable a number of cars to enter, and then to install a ventilating system of such nature that the same

Section showing location of pipettes from front (east) end of building.



PLAN.



END ELEVATION.

Sketch showing location of pipettes for gas analyses and various automobiles and trucks during tests at Experimental Building, Passaic wharf, Newark, N. J.

could be increased or decreased in capacity as occasions might demand.

Accordingly, a building 125 feet in length, twenty-five feet in width and fifteen feet in height was constructed on the Passaic Wharf property of Public Service Railway Company at Newark. The cross-section of the building was an exact duplicate of the interior of the proposed tunnel. The interior of the building was lined with beaver board so that a smooth and uniform surface was obtained. When the doors were closed the building

was practically airtight. Over the ceiling and under the floor spaces were left for ventilating ducts, which were installed and supplied with a number of openings controlled by dampers. The openings in the ceiling were twenty-five feet on centres, while the openings at the floor, which were in both the curb and walkway, were twelve and one-half feet on centres, placed diagonally opposite each other. The ducts were cross-connected at the rear of the building, so that the system could be interchangeable if required. The ducts were then brought down to exhaust and supply fans, which were installed in a small shed at one end and at the side of the building. These fans were built by the Buffalo Forge Company of approximately 15,000 cubic feet of air per minute capacity, and were belted to direct current variable speed motors, which in turn were controlled by regulators, so that the speed and capacity of the fans could be varied as desired. In this fan room were also installed two Ellison draught gauges, one for each fan, so that constant readings as to the volume of air handled and frictional resistance could be carefully tabulated.

In the building, or improvised tunnel section, were operated eight automobiles, comprising two Ford Roadsters, three Cadillac Touring cars and three Packard trucks, which would give about the same conditions as would be found in a section of the tunnel if it were actually constructed.

There were various tests made, as follows:

1. Cars running normally, with no ventilation.
2. Cars racing, with no ventilation.
3. Cars running normally, with air being blown in at ceiling and exhausted at floor.
4. Cars racing, with air being blown in at ceiling and taken out at floor.
5. Cars running normally, with air being blown in at the floor or road line and exhausted at ceiling.
6. Cars racing, with air being blown in at floor line and exhausted at ceiling.

Chemical analyses of contaminated air were undertaken by Prof. Gellert Alleman, of Swarthmore, Penna. He was aided by Dr. H. Jermain Creighton, Assistant Professor of Chemistry, Swarthmore College, and Messrs. R. L. Hill and L. T. Sherwood.

It was considered necessary to make accurate determinations of the contaminated air near the floor, ceiling and the sections

intervening between the floor and the ceiling. The contaminated air was collected in cylindrical pipettes over mercury. These pipettes were twenty-two centimetres long and four centimetres in diameter, and had a volume of approximately 250 cubic centimetres. Each pipette held about eight pounds of mercury. The pipettes were closed at each end by a glass stopcock. In order to prevent the pipettes from breaking under the weight of mercury when suspended for collecting samples, each pipette was suspended with a heavy canvas jacket to the top of which a loop of wire was attached. Eighteen pipettes were used in the experimental tunnel at one time. Nine of these were suspended one-quarter the distance from either end. Each set of nine was arranged as follows: three midway between the top of the tunnel and the bottom, and three at one-quarter the distance from the roof and the floor.

After the engines of the automobiles had been operated for a definite length of time a number of men entered the experimental tunnel, opened the top stopcock of the pipettes, placed pitchers under the bottom stopcock and then opened the latter, allowing the mercury to flow into the pitchers. As the mercury ran out the pipettes were filled with the air and other gases in the tunnel. When the mercury had left the pipettes both stopcocks were closed. In this way eighteen samples of the contaminated air at a like number of points uniformly distributed throughout the tunnel were obtained for each test. These samples were then analyzed.

Solutions were employed for the absorption of the components of the contaminated air to determine the relative quantities of the following:

1. Carbon dioxide.
2. Unsaturated hydro carbons.
3. Oxygen.
4. Carbon monoxide.

The residue unabsorbed was assumed to be nitrogen.

From a very elaborate and convincing analysis Professor Alleman reported that when all doors were closed and the ventilators open and exhausting from the top of the tunnel, and after the engines of eight cars had been "running light" for forty minutes, the condition of the atmosphere was almost normal so

far as physiological action was concerned and the carbon-monoxide content not dangerous. This conclusion was further supported by the fact that the eighteen persons who remained in the tunnel during the test for a continuous period of forty minutes experienced no unpleasant sensations from breathing the air and no subsequent distress.

The contaminated air analysis for this particular test was as follows:

Unsaturated hydro carbons	0.01 per cent.
Carbon dioxide	0.06 per cent.
Oxygen	20.54 per cent.
Carbon monoxide	0.075 per cent.

which proved that the percentage of carbon monoxide was so small as to be negligible.

From the data obtained it was figured that supply fans with a maximum capacity of 360,000 cubic feet of fresh air per minute and the exhaust fans some twenty per cent. more capacity would be required to ventilate the tunnel. In all it was figured to provide a maximum of 750 horsepower to operate these fans and the maximum static pressure that the supply fans would be required to operate against was five inches to six inches.

The system of exhaust and supply fans in the tunnel was to operate from four stations:

> One to be situated between the portal and the fresh or foul air shafts (built at the bulkhead line) on the New Jersey side and ventilating this approach only.
>
> One at the base of the New Jersey shafts and ventilating that portion to the centre line of the tunnel.
>
> One station on the New York side, duplicate of that at the base of the New Jersey shafts.
>
> One midway between the New York shafts and the New York portal, ventilating this approach only.

The first, second and third stations were to be equipped with both supply and exhaust fans, and the fourth station, or that on the New York approach, was to have exhaust fans only, since this approach was but 1400 feet long.

The fans at the various stations were to be made up of several small units so that air quantities could be varied according

to the traffic and thereby keep down the cost of ventilating to a minimum.

In the early part of the year 1917 Mr. Thomas N. McCarter, President of the Public Service Corporation of New Jersey, made public the tunnel report, hereinbefore referred to, which had been prepared for that Corporation by experts retained by it. The Company's purpose, as explained by Mr. McCarter, was not to advocate any special plan but to demonstrate the feasibility of a tunnel from practical engineering and financial standpoints and to urge that one be constructed as soon as possible by the States of New York and New Jersey. His idea was to show that if the tunnel were not operated as a free public highway, similar to the bridges over the East River, it could be profitably operated as a private enterprise and that highly favorable results would be obtained.

He explained that his corporation had no selfish interest in the proposition as a profit-bearing utility, but was heartily in favor of the project, because it would spell progress for metropolitan New York and the whole State of New Jersey. All of the data obtained by the corporation at its own expense were placed gratuitously at the disposal of the Interstate Bridge and Tunnel Commission, and the public authorities were put on notice that if the governmental agencies did not act within a reasonable length of time after the return to normal business conditions, the corporation would seek State authority to finance and operate the project on its own account, charging tolls as a means of reimbursing itself for its investment.

Since that time, as well as before, the proposition has been given serious consideration by the Interstate Bridge and Tunnel Commissions of New York and of New Jersey. In New Jersey legislation has been enacted to enable the State to join with New York in the construction and operation of a tunnel. Like arrangements are under consideration by the State of New York. Besides, there is a bill now before Congress that provides for $6,000,000 as the Federal Government's contribution toward the construction of this tunnel.

It is hoped with peace at hand and industrial conditions readjusting themselves, this much needed improvement, that will affect the convenience, the comfort and the cost of living of 7,000,000 inhabitants, will be carried to fruition.

THE VISIBILITY OF AIRPLANES.*

BY

M. LUCKIESH.

Physicist, Nela Research Laboratory.
National Lamp Works of General Electric Co.

1. FOREWORD.

THE object of the investigation described below was to analyze the various aspects of the visibility of airplanes, to ascertain the possibilities of attaining low visibility in various phases of airplane activities, to arrive at specific practical recommendations, and to eliminate guesswork by supplying a scientific foundation consisting of measurements for the solutions of the problems involved in obtaining low visibility. The war closed before some of the many interesting details could be thoroughly unraveled, but the fundamental data upon which the attainment of low visibility for airplanes may be founded, are presented in this paper. The work was conducted primarily for the Science and Research Division of the Bureau of Aircraft Production from whom permission for publication has been granted. The original reports contained a number of illustrations in color which will not be reproduced in this paper. Furthermore, it does not appear profitable to present all the details of the original discussions and recommendations.

2. INTRODUCTION.

We distinguish objects through differences in light, shade, and color, or, in other words, through differences in brightness and color. Form is sometimes included in such a statement, but this is unnecessary inasmuch as form is determined by the distribution of light, shade, and color. If, then, an object is seen and recognized owing to a distribution of brightness and color which is different from that of the surroundings, it follows that it will be invisible if no such differences exist or the object will be of low visibility if these differences are minimized. In striving for low visibility we must strive for distributions of brightness and color in the object similar to that of its environment or the background against which it is viewed.

* Based on a paper presented at a meeting of the Section of Physics and Chemistry held Thursday, January 9, 1919.

Many decades ago we learned lessons from nature in the art of concealing coloration and one of the fundamental precepts of Nature's camouflage is that an object of a uniform brightness and color is not as inconspicuous amid the usual natural environments, in which variety in light, shade, and color is infinite, as an object of broken color and brightness, in which the average hue and the average brightness approximate those of the environment. (See Reference 1.) Hence pattern is nearly always an essential feature of successful camouflage. An exception is such a case as a uniform blue sky for a background.

We have learned this lesson in certain types of camouflage and should apply it in certain types of camouflage for aircraft. Invisibility is the dominant note of land camouflage. Invisibility was for some time the chief aim of marine camouflage but the submarine menace with its short range of effective attack has caused "confusibility" to replace "invisibility" for the protection of many vessels. In the case of a submarine attack, for example, on a vessel a mile distant there is no possibility in ordinary weather for "invisibility" to save the vessel. However, "confusibility," by rendering it difficult or even impossible for the submarine commander to judge the exact course of the intended victim, may result in a miss, which, according to the old adage, "is as good as a mile."

The program of study of airplane camouflage included chiefly two general viewpoints, namely, above and below the airplane for invisibility. Unfortunately the solutions of these two problems are usually more or less opposed to each other. When viewing the craft from underneath, the background is the bright sky and clouds whose aspect changes sometimes from minute to minute, and when looking down upon the airplane the background is usually the much darker earth whose aspect changes from season to season, owing to the variation in the earth's cloak. The sky is a uniform background only on a cloudless day or on a perfectly overcast day. A clear blue sky and a dense overcast sky are of lower brightness than sunlit clouds and hazy or lightly overcast skies. A sunlit cumulus cloud will often be many times brighter than an adjacent patch of blue sky. The greatest difficulty, however, is due to the extremely greater brightness of the sky than that of objects in the air as seen from below.

Obviously the character of camouflage which is predominantly

required will depend upon the type of airplane, such as bomber, scout, chasse, patrol, etc.; upon the height at which various aerial operations are carried out, and upon various other characteristics of service.

3. MEASUREMENTS AND OTHER OBSERVATIONS.

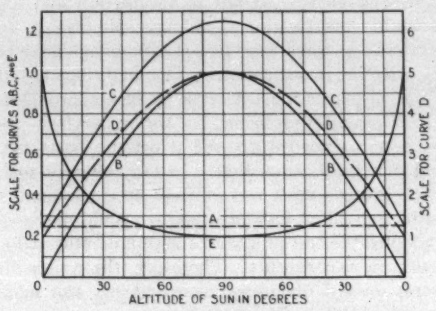
It becomes evident early in the consideration of the problem of lowering the visibility of airplanes that various measurements could be readily obtained which would provide a firm basis for the actual work. In all branches of camouflage there has been much time and energy wasted in speculation and experiments which scientific investigation would have eliminated. In fact, the only certainties in some branches of camouflage have been established by scientific investigations. The final steps in reducing the visibility of airplanes must necessarily be compromises as is the case in most practical problems, but the writer feels assured that the data herein recorded provide a definite basis for practical work and successful camouflage. In fact, without such data the final practical steps must rest entirely upon the qualitative data obtained by individual judgment and we could not be assured of having adopted the best procedures within months and even years of cumbersome experiments. Therefore, the writer directed his first efforts toward obtaining measurements and making other observations which would establish:

1. The relative brightness or apparent reflection-factor of various earth areas.
2. The mean relative brightness or apparent reflection-factor of the earth.
3. The mean relative brightness of water areas.
4. The mean hue of the earth areas.
5. The mean hue of water areas.
6. The size of pattern for airplane camouflage.
7. The shape of pattern for airplane camouflage.
8. Certain brightness measurements in terms of the brightnesses of the sky and of clouds.

The measurements and observations presented in the following may not, in all cases, appear to be of direct interest in solving the problems which have been attacked, but a detailed knowledge of these various aspects is essential for obtaining a full grasp of the possibilities and expedients to be adopted in rendering air-

planes of low visibility in general. Thousands of measurements have been made but these will be presented in condensed form. Numerous cross-country flights were made besides many short flights on various types of days and under various natural lighting conditions—a total of 60 hours of flying, or about 5000 miles of air travel having been devoted to the work. Most of the work was carried out at Langley Field, Hampton, Va., but cross-country flights were made from this point to Washington and Richmond, and over the Chesapeake Bay and Atlantic Ocean.

FIG. 1.



Theoretical relations of the illumination intensities of sunlight and skylight on a horizontal plane.

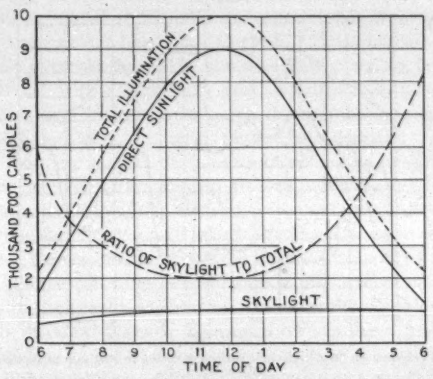
4. SOME THEORETICAL CONSIDERATIONS.

Before presenting the measurements which have been made and the final discussions of the possibilities of obtaining low visibility a few theoretical and practical aspects will be discussed.

The relation of sunlight to skylight is theoretically considered in Fig. 1 (see Ref. 2). For this purpose the brightnesses of a horizontal white diffusing surface and a shadow upon this surface may be determined. The light from a clear blue sky does not vary greatly in intensity during a considerable portion of the day. However, the amount of direct light from the sun falling upon a horizontal surface varies from zero at sunrise to a maximum at noon and at zero at sunset. For the purpose of discussion the illumination upon a horizontal surface due to direct sunlight at noon is assumed to be four times that due to light from the sky, and for simplicity the amount of light from the sky is assumed

to be constant from sunrise to sunset. The illumination intensities due to the sun and sky respectively under the assumed conditions are shown in Fig. 1, curve A being the constant illumination due to the sky and curve B the illumination due to the sun throughout its entire range of altitudes, which is represented on the horizontal scale. Curve C represents the combined illumination from sun and sky. The vertical scale for curves A, B and C is on the left of the figure. The broken curve D represents the ratio of the combined illumination due to the sun and sky to that due to the sky alone; that is, it represents the ratio of the brightness

FIG. 2.



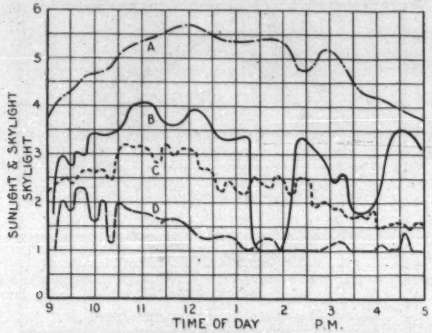
Relations of illumination intensities of sunlight and skylight on a horizontal plane on an extremely clear day.

of the test surface receiving the combined light from the sun and sky to the brightness of a small shadow upon the surface which receives only skylight. In other words, it is obtained by dividing the ordinates of curve C by those of curve A and the values of this ratio are represented on the vertical scale at the right. Curve E is the reciprocal of curve D; that is, it represents the ratio of the brightness of the shadow on the test surface to that of the surrounding portion of the test surface which is illuminated by light from both the sun and the sky. Its vertical scale is on the left of the figure. While natural conditions will not be found to be so uniform throughout an entire day, the data shown in Fig. 1 are

interesting and useful for obtaining an idea of the natural lighting conditions on a clear day. The data obtained on clear days do not differ very much from the theoretical curves of Fig. 1. In Fig. 2 are represented the conditions on an extremely clear day.

Representative data are presented in Fig. 3 for four characteristic days. The measurements were made continually from 9 A.M. until 5 P.M. Curve A represents the ratio of the brightness of the surface receiving both sunlight and skylight to the brightness of a small shadow on the same surface which receives only skylight on a very clear day. The sky was a deep blue and no

FIG. 3.



Ratio of total illumination on a horizontal surface outdoors to that due to skylight alone on various days.

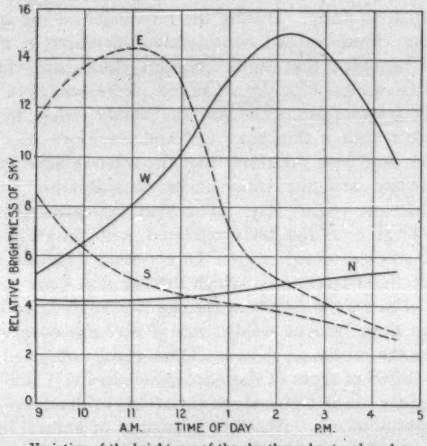
definite clouds appeared during the entire period of eight hours—a very rare condition in most localities. It will be noted that during midday the skylight was only one-fifth to one-sixth as intense as the combined intensity of sunlight and skylight. In other words, during midday the sun contributed about four or five times the amount of light that the sky contributed on this clear day. At observatories, high in the mountains, on very clear days it has been found that as little as one-tenth the light which reaches the earth comes from the sky, the remaining nine-tenths coming directly from the sun. The tendency for the ratio to increase toward noon corroborates the conclusions arrived at in the theoretical treatment of the conditions on a clear day, as shown in

curve D, Fig. 1, and also in Fig. 2. It should be noted that these observations did not extend from sunrise to sunset, which was the time interval used in the theoretical discussion in Fig. 1. Curve B in Fig. 3 represents data obtained on a day during the morning of which a few large cumulus clouds moved slowly across the sky. The sunlight reflected from these clouds increased the relative amount of diffused light, or light from the sky, with the result that the ratio under consideration was smaller than on a clear day. About 1.30 P.M. massive clouds obscured the sun, so that for a time no shadow was perceptible upon the test surface and the ratio became equal to unity. During the remainder of the afternoon the moving clouds caused considerable variation in the ratio. It should be noted that sunlit cumulus clouds are very much brighter than a clear blue sky. Curve C represents data obtained on a thinly overcast day. The sun was plainly visible, but the sky was overcast with a thin hazy veil and therefore was brighter than a blue sky, with the result that the relative amount of skylight increased and the ratio under consideration was much smaller than on a clear day. The hazy veil grew thicker and therefore brighter as the day progressed, with the result that the ratio gradually decreased. Curve D represents data obtained on a day during the afternoon of which the sky was quite completely overcast. During the forenoon the sky was covered with broken clouds, but these became welded into a uniform covering about noon, with the results as shown. Thus, results obtained on four distinctly different types of days are shown in Fig 3, and the data give some idea of the tremendous variations in the distribution of natural light outdoors. Absolute intensities of natural light have not been considered in the foregoing, because they are of minor interest.

Inasmuch as the sky is usually a prominent feature, a few facts regarding it may be of interest. Except at altitudes near that of the sun, a clear blue sky is usually considerably brighter at the lower altitudes—near the horizon—than at the zenith, due largely to the greater haziness noticeable at the lower altitudes. This is perhaps always true, excepting when dense clouds, which are not recognized as clouds, are gathering near the horizon. A clear blue sky is darker than an overcast sky except in the extreme cases of the latter. A slight haze or thin veil of clouds increases the brightness of the sky very much and therefore increases the

amount of light which illuminates many shadows. The color of the sky when clear is more saturated than under any other condition, varying from this deep blue to the neutral gray of an overcast sky. The extreme non-uniformity of the brightness of clear blue or overcast skies is only revealed by measurement. Often a sky which appears quite uniform will vary in brightness at different points by several hundred per cent. A clear sky is usually brightest at those altitudes near the sun, which becomes

FIG. 4.



Variation of the brightness of the sky throughout a clear day.

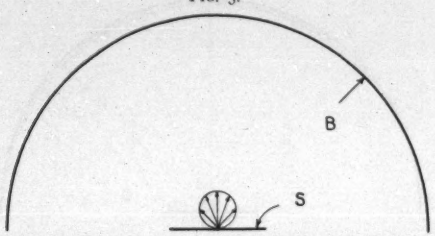
more marked on hazy days when the atmosphere contains more reflecting particles. This is illustrated by means of Fig. 4, the data shown having been obtained on a clear day when the sky was very slightly hazy. The letters on the four curves stand for east, west, north, and south respectively. The brightness of portions of the sky, about 20 degrees above the horizon and approximately at the four points of the compass, were measured during a day in August from 9 A.M. to 5 P.M. at a point near 40 degrees north latitude. No definite clouds were visible during the period of observation. It will be noted that the brightness of the sky was greatest in the east in the morning and greatest in the west

during the afternoon. On a perfectly clear day when the sky was a deep blue, the variations of sky brightness were not so great. The recognized constancy of north skylight is also shown in this illustration.

In dealing with the problems of lighting it is necessary to distinguish between illumination and brightness (cause and effect respectively); to appreciate the difference between the conditions and effects on sunny and overcast days; and to be familiar with certain characteristics of reflecting and transmitting media.

If a hemisphere (Fig. 5) of uniform brightness B is solely responsible for the illumination of the surface S, the brightness of S will equal B if S is perfectly reflecting. Furthermore, this

FIG. 5.



Diffusely reflecting surface S illuminated by hemisphere of brightness B.

would hold if S were either a polished or a diffusing surface. Inasmuch as the reflection-factor R of a surface is never unity, the brightness of the surface S under the above conditions is equal to RB. If the object were perfectly transparent, obviously the brightness B would be seen through the object, but if it had a transmission-factor of T then the brightness as seen through the object would be reduced to TB.

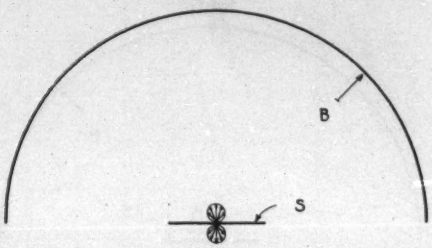
If the object were perfectly diffusely transmitting, its brightness would be only 0.5 B because one-half the incident light is diffused back toward the hemisphere as indicated in Fig. 6. The foregoing condition is representative of that on a perfectly overcast day or before sunrise and after sunset. Obviously the upper limit of brightness in the case of diffusely transmitting media is only one-half that of reflecting media.

At noon on clear days the illumination of a horizontal surface is due chiefly to direct sunlight. Of course the ratio of direct

sunlight to skylight at the earth's surface varies considerably owing to clouds, haze, etc., but of the total light reaching the earth's surface at noon the direct sunlight constitutes as much as 0.9 on extremely clear days. A common value is in the neighborhood of 0.8. This has an intimate bearing upon the visibility of airplanes as viewed from below.

In Fig. 7 we have reproduced the conditions of Fig. 5 with the superposition of direct sunlight at midday. The hemisphere may be considered to represent the sky of brightness B. If the surface S is perfectly diffusely reflecting, its brightness due to the skylight alone is B. Its brightness due to the direct sunlight alone

FIG. 6.



Diffusely transmitting thin object S illuminated by hemisphere of brightness B.

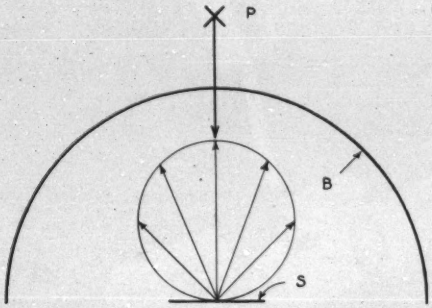
we will assume to be 4 B, which is a fair average. Hence we would have a total brightness of 5 B. If the reflection-factor of the surface is equal to R, then the total brightness is 5 RB.

Assuming the object to be perfectly diffusely transmitting, its brightness would be 2.5 B and, therefore, when viewed against the sky it would appear 2.5 times as bright as the sky. Ordinary translucent media are far from perfectly diffusely transmitting, hence the brightness is 2.5 TB, where T is the transmission-factor. If T were equal to 0.4, under the conditions assumed, we would have the brightness as viewed from below equal to $2.5 \times 0.4 \times B = B$. In other words, if the object were diffusely transmitting with $T = 0.4$ on a clear day when the sun contributed 0.8 of the total light on a horizontal surface at midday, this translucent object, as viewed from beneath, would be of the same brightness as the sky. However, it would not be invisible, because it would appear yellowish in color owing to the fact that most of its

brightness is due to sunlight which is yellow in contrast with the blue skylight. The medium may be colored a blue tint to counteract this. (See Ref. 2, Chapter VII, and Ref. 3.)

This discussion is introduced at this point to indicate reasons for obtaining the measurements which are presented in some of the sections which follow. It is resumed again (Secs. 15 and 16) in connection with the practical considerations of low visibility for airplanes which are treated in later sections.

FIG. 7.



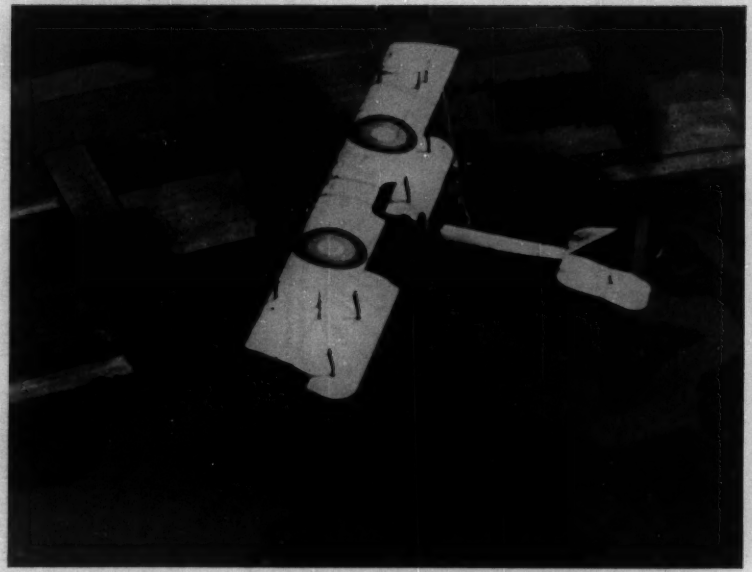
Diffusely reflecting object S illuminated by hemisphere of brightness B and by a point source of light P. Simulating conditions at noon on a perfectly clear day when sun is contributing 0.8 of total light.

5. RELATIVE BRIGHTNESS OR APPARENT REFLECTOR-FACTOR.

To apply the term reflection-factor (commonly called reflection-coefficient) to the earth's surface which has "depth" is somewhat misleading; however, as viewed from an appreciable distance above the earth, this term is not misapplied from a practical standpoint. The term "relative brightness" will be used occasionally and, unless otherwise stated, will mean the brightness relative to a perfectly reflecting and diffusing opaque surface under the same illumination. Obviously the reflection-factor of this theoretical white surface is equal to unity so the values of "relative brightness" may also be considered "apparent" reflection-factors.

In the following table the individual values are means of many observations, and a sufficient number of these are presented to show the consistency of the results. All were made within 150 miles of Langley Field. Further comment on these various types

FIG. 8.



Illustrating character and approximate relative brightness of typical earth areas.

of areas will be found in following sections. Measurements, unless otherwise stated, were made vertically downward from the airplane and usually at altitudes from 1000 to 5000 feet. The brightness measurements were made with different types of instruments in terms of the brightness of a white diffusely reflecting (or transmitting) surface receiving the same illumination. These

TABLE I.

Relative Brightnesses or Apparent Reflection-Factor of Various Types of Earth Areas in Per Cent.

(These were determined in eastern Virginia within 150 miles of Hampton. In all cases the surfaces were viewed from points directly above them, varying from an altitude of 1,000 feet upward. The individual values in the following table are means of numerous measurements. In some cases hundreds of measurements were made during a single flight.)

		Fields	Barren Land	Woods	Inland Water
Aug. 30, 11 to 12.	Generally clear	7.4	10.4	4.9	5.7
Aug. 30, 2 to 3.	Sunny with large clouds scattered	9.3	10.3	4.9	9.0
Aug. 31, 11 to 12.	Generally clear, some thin hazy clouds	6.1	10.1	4.4	6.7
Aug. 31, 1 to 2.	Fairly clear, some clouds	5.8	11.1	3.8	6.2
Sept. 3, 11 to 12.	Sunny, with large scattered clouds	7.9	15.9	3.9	6.3
Sept. 3, 1 to 2.	Generally clear	7.0	19.0	4.6	7.1
Sept. 3, 3 to 4:30.	125-mile trip across country east and south	6.8	17.1	5.0	6.2
Sept. 4, 11 to 12.	175-mile trip to Richmond, Petersburg and return	6.5	13.8	4.5	7.4
Sept. 6, 11 to 12.	Overcast sky	6.7	13.6	4.4	9.1
Sept. 7, 1 to 2.	Clear day	6.3	....	...	7.6
Sept. 9, 11 to 12.	Clear day	...	11.2	3.6	6.7
Sept. 9, 2 to 3.	Clear day	6.7	14.2	3.9	4.4
Sept. 10.	On trip to Washington and return	5.2	8.7	3.5	5.2
	Mean	6.8	1.30	4.3	6.8

Shadow of cloud on earth's surface is less than 1 per cent. Dense clouds up to 78 per cent.

values were then reduced to values in terms of a perfect white. Obviously such measurements had to be made below the clouds when the latter were present. Many measurements were made at various altitudes up to 20,000 feet, although for earth measurements the effect of the low-lying haze was reduced to a minimum by making the measurements vertically downward and at low altitudes. Most of the measurements were made during the middle of the day because instrumental errors were less at this time. However, no extensive differences were obtained in the results

at various times of the day or even on sunny and overcast days. In Fig. 8 is seen a fairly satisfactory photographic reproduction of the relative brightnesses of the various types of areas represented in Table I. A close study of this photograph with the mean values of the Table I in mind is quite interesting.

6. LANDSCAPE.

During the period in which the foregoing observations were made the landscape was still predominantly green, although in some areas there was a slight tinge of yellow common to late summer. It seems reasonable to assume that this season of the year represents a fair mean of the conditions during the chief period of active warfare in this zone. There were many ploughed fields barren of vegetation and others which were not entirely covered by green foliage. In the territory of eastern Virginia there is a great deal of wooded country including wooded swamps, so it appeared, among other reasons, best to keep separate records for the different types of earth areas. Furthermore, there are various kinds of soil, so that the variations in the values in Table I are to be expected. However, the consistency of the observations on woods and fields covered with crops and also on water was surprising. The greatest variations were found for barren land.

The mean relative brightness or apparent reflection-factor for a landscape will depend upon the proportions occupied by the various types of areas. This is another reason for obtaining mean values for the various types of areas. It may be of interest at this point to refer to some of the photographs of landscapes which are included in this paper.

Attempts were made to estimate the proportions of different types of areas present in the landscapes studied. This could be fairly accurately determined for any given part of the country by cross-country flights, during which a record of time in passing over the various types of areas could be kept. If the airplane speed were approximately constant this would give a fairly satisfactory mean value for the relative brightness or the apparent reflection-factor of the terraine. This was done a number of times. For example, the mean value obtained during a 175-mile trip from Langley Field to Richmond to Petersburg and return was about 7 per cent. However, it should be noted that this portion of the country contained much wooded area, although

the course was generally maintained over the more cultivated regions.

Notwithstanding the writer's familiarity with brightness measurements of landscapes, the generally low values obtained in this investigation were surprising. However, these may be accounted for by considering the earth's surface more in detail. On looking down upon such areas as fields, woods, etc., one sees a mixture of highlights and shadows. Much of the area receives only skylight which is only a small part of the total light reaching the earth on sunny days. Even on overcast days the shadows receive only a small portion of the total light reaching the earth's surface. For example, a grass area possesses "depth" similar to velvet. Black velvet has a very low reflection-factor (about 0.4 per cent.), but ordinary blotting paper colored with the same dye will possess a diffuse reflection-factor of about 2 per cent. The depth of the velvet fibre provides light traps and shadows with the result that the reflection-factor as a whole is much lower than that of a single fibre. In a similar manner grass plots, cornfields, ploughed ground and woods provide light traps and shadows so that the mean brightness or apparent reflection-factor is materially reduced.

For example, let us assume that the reflection-factor of a blade of grass is 0.16; that the sun contributes 0.8 of the total light; and that the normal aspect of the grass plot is one-half shadow and one-half highlight. If the brightness of the sky is equal to B, then the brightness of a perfectly white horizontal reflecting surface will equal B, due to skylight alone, and equal to $5\,B$, due to sunlight and skylight. The brightness of the blades of grass receiving both skylight and sunlight will be $5\,B \times 0.16 = 0.8\,B$. The brightness of the grass in shadow, assuming the shadows to receive full skylight (they actually receive much less), will equal $0.16\,B$. The mean apparent brightness will be equal to $\frac{1}{2}(0.8 + 0.16\,B)$. The mean apparent reflection-factor would then equal $\frac{0.48\,B}{5\,B}$, or 0.1 approximately. Thus it is seen, with these assumptions, the apparent reflection-factor of the grass plot as a whole is much less than that of individual blade which was assumed to be 0.16. It will also be noted that the trapping of light by virtue of the "depth" of such a surface was not considered in the foregoing analysis. Woods are strikingly dark

owing to these reasons, and on the whole these considerations prepare us to expect a surprisingly low mean apparent reflection-factor of the earth. Bare earth which has been packed by rain and baked by the sun is conspicuously brighter than the same soil freshly ploughed even after the latter has dried. It is commonly noted that wet dirt is darker than the same dirt when dry. For example, a blotting paper which, when dry, reflected 0.74 of the incident light, reflected only 0.54 of the incident light when wet. The brightness of all earth areas does not vary much with the angle at which they are viewed. This is not strictly the case with the surface of water as will be noted later.

Although an overwhelming number of the values of apparent reflection-factor or relative brightness are included within a range from 3.5 per cent. to 10 per cent., the following ranges include practically all the values obtained for the different types of areas:

Ploughed and barren ground	0.10–0.20
Grass, fields	0.05–0.10
Woods	0.03–0.05
Inland water	0.05–0.10

The values for water are included here for the sake of interest, but owing to the special character of its surface reflection it is discussed at length in Section 9.

The change in Nature's cloak during the various seasons must be considered, but the most intensive activities in warfare are carried on from spring to fall usually and, therefore, the summer garb of Nature is here considered of chief importance. The reflection-factor of snow can be assumed to be equal to that of commercial white pigments and the values for barren ground in Table I will hold for winter. It would not be difficult to make a fairly accurate estimate of the apparent reflection-factors of various types of areas for late autumn after the experience accumulated in the present investigation. From such values fairly successful camouflage could be developed for these seasons.

A number of flights were made during the middle of October in order to obtain certain measurements of apparent reflection-factor of earth areas and observations of the hues of the autumn landscape. These observations were not as exhaustive as those recorded in Table I and on other pages, because as has been stated, we are concerned primarily with the summer landscape. The

results obtained for the apparent reflection-factors or the brightnesses relative to a perfectly white surface are:

Fields	6.0 per cent.
Barren land	11.3 per cent.
Woods	4.3 per cent.
Inland water	5.5 per cent.

The landscape was decided brownish and generally dull in character. Few green areas were present and the woods displayed a variety of tints. It is noteworthy that the landscape in general appeared more dull and dead from high altitudes than was expected. Although the number of observations was limited to hundreds instead of thousands, as in the investigation conducted during midsummer, it will be noted that the results are not widely different. To obtain low visibility for airplanes viewed from above the brightness would be about the same for late autumn as for summer, but obviously the color would be changed from a very dark olive green to a dark brown or dark greenish-brown. It does not appear practicable to alter the camouflage for airplanes for the autumn season which is relatively short with the possible exception of a relatively few craft. The dark olive green craft would still be of fairly low visibility as viewed from above during the autumn.

7. CLOUDS.

Sunlit clouds are often several times brighter than an adjacent patch of blue sky. This increases the difficulty of realizing low visibility when viewing the airplane from below against the clouds. When the clouds are below the observer they are of course many times brighter than the earth background when they are illuminated by both the sun and the sky. Some measurements were made in the course of these investigations in order to establish the magnitude of the relative brightness or apparent reflection-factor. These values vary considerably with the character of the cloud and the lighting conditions.

The apparent reflection-factor of cumulus clouds receiving full skylight and sunlight as measured vertically above them on various days, varied with the density of the clouds. The mean

values of the upper surface of clouds, determined on different days, were found to be as follows:

Very dense clouds (Fig. 9)	0.78
Dense clouds, quite opaque	.62
Dense clouds, quite opaque	.59
Dense clouds, quite opaque	.55
Dense clouds, nearly opaque	.44
Thin clouds	.40
Thin clouds, (Fig. 20)	.36

One day when the sky was very heavily overcast, with the exception of a small rift which admitted the airplane with safety to the upper region, a great many measurements of the brightness of the upper surface of the clouds were made. These observations were made near the sunny side of the hole in the extended massive layer of clouds and the values of relative brightness obtained varied from 0.7 to 0.8 with a mean of 0.78. The character of the clouds as seen from above is illustrated in Fig. 9. Inasmuch as the upper side of a cumulus cloud was found to be six times brighter than the lower side, we must conclude that there is a "mass" effect unless we choose to conclude that there is a tremendous absorption. In other words, great masses of clouds can be relatively much brighter than a purely diffusing non-absorbing medium in a thin layer, which theoretically would possess a transmission-factor equal to 0.5 and a reflection-factor of the same value.

The sunlit surfaces of dense clouds were found to be commonly 5 to 10 times the brightness of the adjacent patches of clear blue sky. Ordinary cumulus clouds provide a screen for airplanes as often as they are backgrounds. Cirrus clouds, owing to their great height, are usually backgrounds when they are present. In Fig. 10 a common condition is illustrated. The photograph was taken from an altitude of about 7000 feet, the cumulus clouds being at an altitude of 4500 feet. The effect of the haze is seen by the obscurity of the distant landscape. Some of the other photographs are of interest at this point, especially in showing the high brightness of portions of the clouds and their lack of uniformity in brightness.

8. HAZE.

Haze usually tends to lower visibility because it absorbs light reflected from the objects which are viewed and chiefly because

FIG. 9.

Above a dense cloud layer several thousand feet in depth.

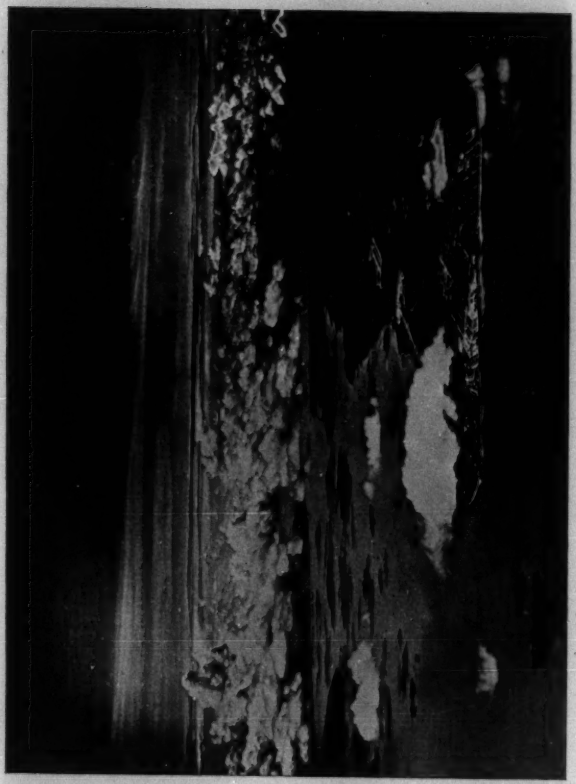


FIG. 10.

Illustrating cloud and haze levels also cloud shadows upon water.

it is a luminous veil. In the regions in which these studies were made, the "dust" or low-lying haze extends ordinarily to an altitude of about one mile. This haze is quite absorbing, as is readily seen in viewing the earth obliquely, and also is fairly luminous. On some days the sky, even at altitudes of 10,000 feet, appears quite bright and very unsaturated in color. This upper haze seems to be of the nature of a very thin uniform cloud. Inasmuch as low visibility of airplanes, as viewed from below, for practical reasons is dependent largely upon a dark sky, this upper haze, when it is at such altitudes as to contribute to the brightness of the sky background against which an airplane is viewed, increases the visibility of the craft. The lower or dust haze operates to lower the visibility of craft at moderate and high altitudes.

No very accurate measurements of the luminosity of the low-lying dust haze were obtained, but attempts were made to obtain the order of magnitude. For example, on a cloudless day brightness measurements of water normal to its surface were made at various altitudes from 1000 to 18,000 feet. Although the values for various areas of the water varied slightly, it appeared that the values were about 25 per cent. higher at extremely high altitudes than at the lowest altitudes. This would indicate that, on this particular day, the net result of the haze was to increase the relative brightness of the earth about 25 per cent. On very hazy days this value may be greater.

A better organized attempt was made to determine the change in brightness of the earth with the altitude of observation on a clear day. In order to determine this it is necessary to have a large earth surface of uniform brightness. The brightness of this surface may be determined as viewed from various altitudes. For this purpose a deep channel in the Chesapeake Bay was selected and its brightness was determined for altitudes up to 10,000 feet. No appreciable change was noted, but unfortunately the day was not very hazy. It is doubtful if the change is very much on very hazy days, because the increase in brightness due to the luminous haze as viewed from above is compensated more or less by the decrease in brightness of the earth due to the absorption by the haze of some of the light reflected from it.

No appreciable variation of the total illumination was noted for different altitudes even on very hazy days. On some remarkably clear days, measurements indicated that the sky contributed

about 10 per cent. of the total light received at the earth's surface at noon with the sun at about 50 degrees altitude. These results were the lowest ever obtained by the author at the earth's surface.

Some measurements of the ratio of upward light to downward light at altitudes of 11,000 feet indicated that about one-tenth as much light was reflected upward as was received downward. Owing to the conditions under which the measurements were made there may be large errors in the results, but they indicate the order of magnitude which checks well with what would be concluded from Table I. Measurements were made of upward light in terms of the sky brightness; that is, of the brightness of a perfectly white horizontal surface illuminated by light reflected upward from the earth, in terms of the brightness of zenith sky. These values were about 1.07 for the particular conditions. Obviously the result depends largely upon the brightness of the sky on a clear day and this varies considerably. The foregoing result was obtained on clear but moderately hazy days. This shows the futility of obtaining low visibility for airplanes, as viewed from below, by merely painting their lower sides white.

The presence and the effect of the earth haze, which ordinarily possesses a fairly definite upper surface at approximately a mile above the earth, are shown in Fig. 11. The "false" horizon due to this dust haze is clearly visible with a few cumulus clouds projecting above it like icebergs. The upper level of this haze is indicated by *H* on the margin of the photograph. The natural horizon *N* is faintly visible below *H*. The remaining portion below *N* is water with the exception of a peninsula of land (Cape Charles), indicated to the left of *L*. Of course, photography cannot accurately reproduce the actual effect of haze on visibility.

9. WATER.

Water forms a part of the background when airplanes are viewed against the ordinary landscape, but it is of little importance individually except as a background for seaplanes. As seen in Table I the mean relative brightness or apparent reflection-factor of inland water, as obtained by measurements perpendicular to its surface, was 0.068. Practically all the values obtained on different days were within the range from 0.05 to 0.1

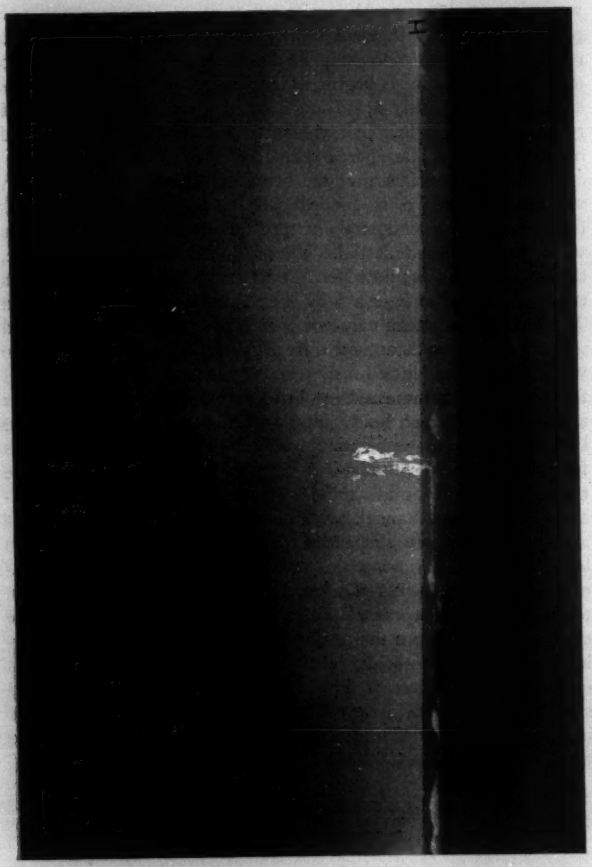


FIG. 11.

Illustrating haze horizon and cumulus cloud level.

and most of them were close to the mean value. If the surface of water is perfectly smooth it will reflect at its surface about 0.02 of perpendicularly incident light. This reflection-factor varies only slightly with increasing angle of incidence until about 50 degrees is reached. It begins to increase more rapidly from this angle until obviously at an angle of incidence of 90 degrees it reflects all the light. All values in this paper were obtained by viewing the surface perpendicularly unless otherwise stated.

Owing to the fact that the brightness of an area of water, viewed from above, is due partially to specular reflection, its brightness will depend partially upon the brightness of the objects whose images are reflected. These objects are blue sky, haze, clouds, and the sun; however, the latter will be neglected in this discussion because it is a very special case. It will be seen in Table I that the mean value of the relative brightness of inland water is fairly constant on different days. In fact, this value varies surprisingly little for deep water which would be considered fairly clear. An increased brightness is noted for shallow water and for water which holds fine particles of earth in suspension. For example, measurements on the James River, about 30 miles from its mouth, gave values of 0.10 for shallow water near the shore and 0.075 in mid-stream. The latter value was very constant for its deep channel. Near Richmond where the river was very yellow, due to suspended particles of earth, the relative brightness rose to 0.20, which is very unusual. Many measurements of the brightness of water viewed normal to its surface in terms of the brightness of the zenith sky yielded a mean value of about 0.87. From the position of the observer directly overhead on clear days, the surface reflected only images of portions of blue sky regardless of the character of the waves. It is thus seen that an overwhelming portion of the brightness of the water is due to the light diffused within it. This is obvious in Fig. 10 from the definite shadows on the water cast by the clouds.

(To be concluded.)

ELECTROLYTIC CONDUCTIVITY IN NON-AQUEOUS SOLUTIONS

III. RELATIONS BETWEEN THE CONDUCTIVITY OF THE SOLUTE AND SEVERAL PHYSICAL PROPERTIES OF THE SOLVENT.*

BY

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In a previous paper,[1] wherein the relations between the dissociating power of a solvent and its other physcial properties were discussed, it was stated that it had been found that the viscosity of the solvent, the degree of association of the solvent, the associating power of the solvent and the dielectric constant of the solvent are all related to its dissociating power. Some years ago, Walden [2] studied the dissociating power of 49 organic solvents with reference to the same solute, *viz.*, tetraethyl-ammonium iodide. The results of his investigations show that while relations exist between the dissociating power of the solvent and the above-mentioned physical properties, the most important of these relations is that which exists between the dissociating power of the solvent and its dielectric constant. Recently, Creighton and Way[3] studied the conductivity of a solute containing the benzol neucleus, *viz.*, trimethyl-para-tolyl-ammonium iodide, in 13 solvents having different constitutional factors: water, alcohols, aldehydes, ketones, acids, nitriles, nitro-compounds and epichlorhydrin. In the present communication, it is proposed to discuss the data obtained by Creighton and Way with reference to some of the physical properties of the solvents.

The viscosity and the degree of association of solvents have long been recognized as being related to the conductivity of electrolytes. As early as 1856, Wiedermann [4] concluded from

* Communicated by Professor Creighton.

[1] Creighton, H. J. M., JOURN. FRANKLIN INST., **182**, 745 (1916).

[2] Walden, P., *Zeitschr. phys. Chem.*, **54**, 129 (1905).

[3] Creighton, H. J. M., and Way, D. H., JOUR. FRANKLIN INST., **186** (1918).

[4] Wiedermann, G., *Pogg. Ann.*, **99**, 229 (1856).

his studies of the conductivity of aqueous solutions of copper sulphate that the conductivity of a solution is directly proportional to the concentration and inversely proportional to the viscosity. From a study of the conductivity of various electrolytes in different solvents, Dutoit and Friderich[5] have reached the conclusion that the values for the equivalent conductivity at infinite dilution for a given electrolyte dissolved in different solvents are a direct function of the degree of association of the solvents, and an indirect function of the viscosity of these solvents. This relation, for the most part, was found to hold only qualitatively. Of much more importance is the quantitative relationship established by Jones and his co-workers,[6] which is expressed as follows: the conductivities of comparable equivalent solutions of binary electrolytes in certain solvents (methyl and ethyl alcohols, acetone, etc.) are inversely proportional to the coefficient of viscosity of the solvent in question, and directly proportional to the association factor of the solvent. By comparable equivalent solutions are meant solutions in which the same number of moles of solvent contain the same number of moles of solute. Expressed mathematically, this hypothesis takes the form:

$$\frac{\Lambda_v' \eta}{x} = \text{constant},$$

where Λ_v' is the equivalent conductivity of comparable equivalent solutions and η and x are the coefficient of viscosity and the association factor of the solvent respectively. At infinite dilution Jones has shown that

$$\Lambda_\infty \eta = \text{constant};$$

and in an extensive investigation Walden[7] has found that

$$\Lambda_\infty^{25} \cdot \eta^{25} = 0.7$$

for solutions of tetraethyl- ammonium iodide in thirty solvents.

The foregoing relations have been applied to the conductivity data obtained for solutions of trimethyl-para-tolyl-ammonium iodide in different solvents. The results obtained are given in Table I.

An examination of the values recorded in the last two columns

[5] Dutoit, P., and Friderich, L., *Bull Soc. Chim.* (3), 19, 321 (1898).
[6] Jones, H. C., and Co-Workers, *Carnegie Publication*, No. 80 (1907).
[7] Walden, P., *Zeitschr. phys. Chem.*, 55, 207 (1906).

TABLE I.

Solvent	Coefficient of Viscosity[8] η^{25}	Association Factor[9] x	v'	$\Lambda^{25}_{v'}$	Λ^{25}_{∞}	$\frac{\Lambda^{25}_{v'} \cdot \eta^{25}}{x}$	$\Lambda^{25}_{\infty} \cdot \eta^{25}$
Acetone	0.00316	1.26	738	138	188	0.346	0.594
Propylaldehyde	0.00435	1.4	720	95.5	120	0.296	0.414
Propionitrile	0.00413	1.45	887	118.3	143	0.242	0.591
Nitromethane	0.00619	1.88	539	98.4	115	0.324	0.712
Epichlorhydrin	0.0103	1.0	789	38	44	0.391	0.453
Benzaldehyde	0.0140	0.97	1018	26.2	33	0.378	0.462
Formic acid	0.0163[10]	3.61	379	73.2	90	0.331	(1.467)
Anisaldehyde	0.0422	1.31	1217	11	13	0.354	0.464
					Mean:	0.33	
Methyl alcohol	0.00580	3.43	404	84.5	100	0.143	0.580
Ethyl alcohol	0.0112[11]	2.74	586	38.8	48	0.159	0.538
Acetic acid	0.0119[12]	3.62	571	16.5	35	0.054	(0.298)
Benzonitrile	0.0125	0.97	1020	41.8	54	0.539	0.675
Nitrobenzol	0.0182	0.93	1026	31.4	38	0.614	0.692
						Mean:	0.56

of Table I shows that for the first eight solvents the value of $\frac{\Lambda^{25}_{v'} \cdot \eta^{25}}{x}$ is approximately constant; while the values obtained for $\Lambda^{25}_{\infty} \cdot \eta^{25}$, with the exception of those for acetic and formic acids, lie about a mean value 0.56. When the errors involved in the determination of the quantities employed are taken into consideration, only an approximate constancy could be expected. The values for the degree of association are only approximate, and different observers give different values for the coefficients of viscosity. For solutions of potassium iodide in methyl alcohol and in ethyl alcohol, Jones [13] obtained for $\frac{\Lambda^{25}_{v'} \cdot \eta^{25}}{x}$ the values 0.1408 and 0.1428, respectively. It is worthy of note that these values are not very different from those for trimethyl-para-tolyl-ammonium

[8] Except where otherwise noted, the values for the coefficient of viscosity are those determined by Walden, *Zeitschr. phys. Chem.*, **55**, 207 (1906).

[9] The majority of these values have been determined by Ramsay and Shields; the remaining values have been determined by other observers by either Longinescu's method or by Traube's method.

[10] Garner, J. B.; Sexton, B., and Parker, H. O., *Amer. Chem. J.*, **46**, 236 (1911).

[11] Baker, F., *J. Chem. Soc.*, **101**, 1411 (1912).

[12] Kernot, G., and Pomilio, U., Soc. R. Napoli, **17**, 359 (1912).

[13] Jones, H. C., *loc. cit.*, p. 71.

iodide in the same solvents. The very low value of $\frac{\Lambda_{v'}^{25} \cdot \eta^{25}}{x}$ for acetic acid is interesting, although at present no explanation can be given.

Since $\Lambda_{\infty}^{25} \cdot \eta^{25}$ has a value of 0.7 for solutions of tetraethyl-ammonium iodide and a value of 0.56 for solutions of trimethyl-para-tolyl-ammonium iodide, it would appear that the value of this constant is dependent upon the nature of the solute.

The conclusions of Dutoit and Friderich [14] and of Dutoit and Aston,[15] that the limiting values of the equivalent conductivity of one and the same solute in different solvents are directly proportional to the degree of association of the latter, and that the conductivity of a solute when dissolved in a non-polymerized solvent is zero, do not hold for solutions of trimethyl-para-tolyl-ammonium iodide in the solvents investigated.

It has been mentioned that of the various relations between the dissociating power of a solvent and its other physical properties, the most important is that which exists between the dielectric constant of the solvent and its dissociating power. According to the Nernst-Thomson hypothesis, that solvent possessing the higher dielectric constant should cause the greater dissociation of the solute at a given dilution. The dissociating power of the solvents under consideration, as expressed by the percentage dissociation of trimethyl-para-tolyl-ammonium iodide at a given dilution, has been calculated for each of the solvents at several dilutions, but only an approximate parallelism has been found to exist between the dissociating power of these solvents and their dielectric constants. This approximate parallelism is shown in Table II, where the percentage dissociation of trimethyl-para-tolyl-ammonium iodide, for dilutions $v = 128$, $v = 1024$ and $v = 2048$, is compared with the magnitude of the dielectric constants of the different solvents.

The values given in Table II for the dissociation of trimethyl-para-tolyl-ammonium iodide show that the magnitude of the dielectric constant is not the sole factor which influences the dissociating power of the solvent. The extent to which the solvent is

[14] Dutoit, P., and Friderich, L., *loc. cit.*

[15] Dutoit, P., and Aston, E., Compt. rend., **125**, 240 (1897).

TABLE II.

Solvent	Dielectric Constant [18] ϵ	Dissociation of trimethyl-para-tolyl-ammonium iodide at:—		
		$v=128$	$v=1024$	$v=2048$
		Per cent.	*Per cent.*	*Per cent.*
Water	81.7	90	95	96
Formic acid	57.0	73	87	89
Nitromethane	38.2–40.4	78	89	91
Nitrobenzol	33.4–37.4	66	83	87
Methyl alcohol	32.5–34.8	79	90	92
Propionitrile	26.5	67	84	87
Benzonitrile	26.0	54	77	82
Epichlorhydrin	26.0	70	85	88
Ethyl alcohol	21.7–27.4	66	84	87
Acetone	20.7–21.9	54	77	82
Propionaldehyde	14.4–18.5	63	83	86
Benzaldehyde	14.5–16.9	59	79	85
Anisaldehyde	15.5	67	85	88
Acetic acid	6.46	..	72	77

polymerized also plays an important rôle. Thus, at a dilution of $v = 128$, while in methyl alcohol with a dielectric constant of 32.5–34.8 the electrolyte is 79 per cent. dissociated; in nitrobenzol with a slightly higher dielectric constant the electrolyte is only 66 per cent. dissociated. On the other hand, the former solvent is highly associated ($x = 3.43$), while the molecules of the latter are not polymerized at all.

The dissociating power of propionitrile, benzonitrile and epichlorhydrin are particularly interesting, as these solvents have dielectric constants of approximately the same magnitude. That polymerization plays a part, however, is suggested by the fact that while the molecules of propionitrile are associated to a considerable extent, those of benzonitrile do not associate. This behavior is in agreement with the results of Schlundt,[17] who found that the conductivities of silver nitrate in these two dielectrically equal solvents gave differences in the sense that the conductivity in benzonitrile corresponds to a smaller ionic concentration. On the other hand, the dissociating power of epichlorhydrin is considerably greater than that of benzonitrile, although the dielectric constants and the degrees of association of these two solvents are approximately the same.

[18] Drude, P., *Zeitschr. phys. Chem.*, 23, 308 (1897); Schlundt, H., *Jour. Phys. Chem.*, 5, 165 (1901); Mathews, J. H., *ibid*, 9, 667 (1905).

[17] Schlundt, H., *loc. cit.*

The dissociation of trimethyl-para-tolyl-ammonium iodide in formic acid is very much smaller than would be expected in view of the high degree of association and the large dielectric constant of this solvent. This may possibly be due to the fact that in formic acid the molecules of many substances associate to polymerized molecules, and in consequence, therefore, the relatively small dissociation of trimethyl-para-tolyl-ammonium iodide may result from the reduction in the number of molecules effected by association being greater than the increase which has its origin in ionization. It may be assumed, in accordance with the equilibrium laws, that a decrease in ionization must result from a large reduction of the active mass of the simple molecules through polymerization, since it is only the simple molecules which are capable of producing ions.

SUMMARY AND CONCLUSIONS.

1. The results of measurements of the conductivity of trimethyl-para-tolyl-ammonium iodide in thirteen solvents have been discussed with reference to the viscosity, the degree of association and the dielectric constant of the solvents.

2. It has been found that the relation established by Jones between the conductivity of the solute, and the viscosity and the degree of association of the solvent holds in a general way for the solvents considered. The Nernst-Thomson hypothesis has been found to hold only approximately.

3. While the relations considered are by no means quantitative, it must be remembered that the data are subject to much uncertainty. The values for Λ_{∞}^{25} have been obtained either by calculation or by graphic extrapolation, and consequently the values for the degree of dissociation of the solute are only approximate. The magnitudes for the degree of association and the dielectric constant of the solvents are also more or less uncertain, and do not in many cases refer to the temperature at which the conductivity measurements were carried out. Further, the relations considered are probably complicated by the association of the molecules of the solute to form polymerized molecules.

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INVESTIGATIONS ON THE ABSORPTION OF WATER BY GELATINE.*

BY

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DURING the last few years we have been almost deluged with extremely interesting theories of physiological behavior which have been drawn from the field of colloidal chemistry. However, the science of colloidal chemistry is still so much in its infancy that it behooves us to desist from making applications for a time, and to take measures to verify our facts. The imbibition of water, and of solutions, by jellies has proved the most fruitful source for speculation, and yet an examination of the literature on this subject shows much contradiction in the results of experimental work. Consequently, it seems very important that more physiologists give time to the accurate study of the imbibitional properties of jellies. This paper contains the facts obtained from work on some of the imbibitional phenomena of gelatine jelly. The results are offered at this time without their theoretical significance in the hope that they may aid other workers in their effort to obtain the facts of imbibition in comparable form; and also that a warning note may be sounded against too readily forming conclusions concerning physiological behavior from work with gelatine or other colloidal jellies before the behavior of the gelatine itself is ascertained.

METHODS.

A former paper[1] described the precautions which I have found necessary to take in order to obtain gelatine jelly that will always show the same imbibitional behavior when treated in the same way. The various methods for the measurement of the uptake of water by gelatine must be considered carefully before an investigation into the influence of various materials, of temperature, or of any other factor upon the absorbing capacity can

* Communicated by the Author.

[1] "Investigations on the Imbibition of Water by Gelatine." Shreve, E. B. *Science:* N. S., vol. xlviii, No. 1239.

be undertaken. Two general methods for measurement of the amount of water imbibed present themselves, namely: (1) increase in weight, and (2) increase in volume.

Tables I and II give some of the results obtained when measurements of weight and volume were made on the same material. From these and other experiments, it is evident that the ratio of

TABLE I.

Comparison of the Number of Grams gain in Weight with the Number of Cubic Centimeters Gain in Volume for Small Disks of Gelatine Jelly. Gelatin = 33 per cent., Distilled Water = 67 per cent. Disks Were Placed in Distilled Water. Each Number Represents the Total Gain for 30 Disks for the Time Indicated.

Method of measurement	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Time
Weight.....	2.68	2.58	2.60	2.60	2.65	2.68	24 hrs.
Volume.....	3.0	4.0	3.5	2.9	2.6	2.8	24 hrs.
Weight.....	5.2	5.2	4.89	4.83	5.28	5.24	48 hrs.
Volume.....	6.1	5.5	5.8	5.4	5.3	4.7	48 hrs.

TABLE II.

Comparison of Gain in Weight with Gain in Volume of Disks of Gelatine Jelly. Both Sets of Readings Reduced to Gain per Hour per Gram of Dry Weight of Gelatine. Gain in Volume Measured by Displacement. Lot No. 1 = 33 per cent. Gelatine and 67 per cent. Distilled Water. Lot No. 2 = 33 per cent. Gelatine and 67 per cent. M Sodium Sulphate. Lot No. 3 = 33 per cent. Gelatine and 67 per cent. M/2 Sodium Sulphate. Thirty Disks of Same Size in Each Lot. All Placed in Distilled Water.

Method of measurement	Lot 1		Lot 2		Lot 3		Time
	A	*B*	*A*	*B*	*A*	*B*	
Weight.....	0.65	0.64	2.08	1.98	0.93	0.93	2 hrs.
Volume.....	0.68	0.73	2.20	1.90	0.96	0.85	2 hrs.

increase in weight to increase in volume is a constant. The increase in volume was measured by the displacement of the liquid which the disks were absorbing. A burette graduated to 0.1 c.c. was used for the readings. When this method of volume measurement was used there was a greater variation between duplicates than when the weighing method was used. Other experiments in which volume was calculated from direct measurement of individual pieces were much less satisfactory. The reason for this is two-fold: first, the time involved in the measure-

ments is too great to allow enough pieces to be measured to insure a good average, and, second, the error in measuring the pieces after they have become slightly soft is very great.

It has frequently been the custom to measure the increase of one dimension instead of the entire volume. In a former article [2] I have given the precautions for the use of this method, when gelatine which has lost water by evaporation is used. The ratios given in Table III bring out the relation between gain in height and gain in weight. Increase in height was measured by the MacDougal auxograph.[3] Three disks were placed under the glass

TABLE III.

Comparison of Increase in Height with Increase in Weight. Disks of 10 per cent. Gelatine Jelly Which Has Not Lost Water by Evaporation Were Placed in Distilled Water (Lot 1), in M/200 Hydrochloric Acid (Lot 2), and in M/50 Sodium Hydroxide (Lot 3). Increase in Height was Measured by Auxograph. Height Readings are Reduced to Number of Centimeters per 100 Centimeters of Original Thickness and Weight Readings to Grams per 100 Grams of Original Weight. Each Number is an Average of Readings Taken on Twenty-four Pieces of Jelly. Ratios Appear in Parentheses Beneath Numbers.

Method of measurement	Lot 1	Lot 2	Lot 3
Weight	21.8	12.1	91.2
	(1.0)	(0.55)	(4.18)
Height	4.8	3.6	19.5
	(1.0)	(0.75)	(4.06)

triangle of each of twelve instruments and the results were averaged.

An idea of the variation between different readings to be expected with the auxograph and with the micrometer calipers may be had from Table IV. The probable variation to be found when the weighing method is used may be seen from many later tables in the paper.

It seems evident that so long as large differences are involved, it makes little difference what method is employed, just so the same one is used for all measurements. However, when the detection of smaller differences becomes desirable, it is then advisable to consider the range of probable variations and the precautions

[2] Shreve, E. B., *loc. cit.*

[3] MacDougal, D. T., and Spoehr, H. A., "Growth and Imbibition." Proc. Amer. Phil. Soc., lvi, No. 4, 1917, p. 329.

necessary in the use of the several methods. It must be borne in mind, too, that the variations may not always be traceable to experimental error, but may be due to the nature of the material.

The results obtained from the measurement of increase in weight show less variation between duplicates than from any of the other methods. This is due to two causes: the first, and most important, being the possibility of using a much larger quantity of material for one reading, and, second, the lower experimental error found in the balances. A convenient unit for measurement is gain in weight per gram of oven-dried gelatine present. In all cases where results are needed no more frequently than once in two hours I have found that the weighing method is most satisfactory.

TABLE IV.

Number of Centimeters Increase per Centimeter of Original Height (Axis of greatest Evaporation) in Rectangles of Air Dry Gelatine (Originally 15 per cent.) When Allowed to Absorb Water for Sixteen Hours. Comparison of Measurements by Micrometer Calipers, with Readings for Auxograph Traces. Original Thickness Measured with Calipers in Both Cases. Each Number is an Average of Measurements on Three blocks.

Instrument										
Auxograph	7.50	6.20	6.20	6.20	6.20	5.20	5.55	6.90	6.50	8.70
Micrometer calipers	8.10	7.00	8.70	7.80	7.60	5.20	5.10	8.60	7.10	8.20

The measurement by hand, of increase in size, is out of the question for reasons mentioned in an earlier paragraph and, furthermore, it has no advantage over the weighing method. The measurement of increase in size by means of the auxograph has distinct advantages in some kinds of work as it gives an automatic record of swelling with time, and in some experiments it is highly desirable to have a continuous record for the first few hours. However, as the gelatine becomes softer with its increasing water-content, the measurement by auxograph becomes more difficult, the weighing method showing an increase in water-content many hours after the auxograph has ceased to show an increase in thickness. Another drawback to the auxograph for most work is the number of instruments required to obtain enough readings to get a reliable average. Only three pieces can be used conveniently under one instrument. However, if a constant temperature room is available many readings may be taken consecu-

tively on the same instrument. The experiments reported upon in the following pages are of such a nature that readings taken every two hours were frequent enough, and consequently the weighing method was used.

Increase in thickness (*i.e.*, along the axis of greatest evaporation) was found to be proportional to increase in volume, but increase in either of the other dimensions was not necessarily so. Thus, when an experiment was made, to discover the influence of size on the water-absorbing rate of certain blocks of gelatine, measurements of thickness, of volume, and of increase in weight showed a slower rate for large than for small pieces; but no such relation could be detected by measurements of breadth. In this case, volume was determined from measurements of thickness and area.

Whatever method is used for the measurement of imbibition, it is necessary, of course, to use pieces of the same size and form when comparisons are made. However, certain small differences in size which occur, because of unavoidable experimental errors, need not be taken into account. It is essential, though, to determine the error that may be neglected in each particular case. For example, it was found that the error is negligible if disks larger than 0.5 cm. in diameter are cut with the same glass rod, or if cylindrical moulds 1 cm. in diameter have a variation of 5 per cent. in diameter.

The same general methods were used in all of the experiments which follow. The jellies used for the absorption tests were made thus: Leaves of "Silver Brand" gelatine were selected of even thickness, the thick edges trimmed off with scissors and the remaining part cut into small squares. These squares were then placed in a large desiccator and dried to constant weight at 40° C., 20 grams were then weighed out, mixed with 50 c.c. of water or of a solution of the desired strength and allowed to stand for three hours. The gelatine with its accompanying liquid was then heated over a water-bath (50°–60° C.) until the gelatine was completely melted. The resulting liquid was well mixed with a glass rod. In those experiments that are marked "disks" the gelatine was then immediately poured into stender dishes of about 12 inches in diameter. These dishes were placed on a small leveling table inside of a refrigerator and left there until the lot had "set", when disks 2 cm. in diameter were cut with a

glass tube having a ground glass edge. The disks were always handled with a gold-tipped forceps and a gold lifter. In some cases these disks were used immediately, and in others they were allowed to lose water by evaporation before they were tested for imbibition. In both of these cases the imbibition tests proceeded in the same manner. The disks were first weighed in covered weighing bottles (7 cm. in diameter) and then transferred to large flat crystallizing dishes and the desired liquids poured over them. The disks were always placed far enough apart to prevent their touching after swelling. At the close of the chosen interval of time the disks were carefully lifted from the solution and transferred to filter paper. They were gently blotted with another piece of filter paper until all free water was removed. The disks were weighed in the bottles and afterwards returned to their solutions. Thirty disks were used for each test. This method gave satisfactory results, but on account of the time involved in handling the disks, it was replaced later by another method in all experiments where the jellies were not evaporated to dryness. This later method was used in those experiments marked "dishes." It was identical with the one just described up to the point where the gelatine was ready to be poured out for the setting. In this case 10 c.c., and later 5 c.c., of the liquid gelatine was drawn off in a pipette and allowed to flow into small cylindrical glass dishes about 6 cm. in diameter and 3 cm. high. These dishes had vertical sides, accurately made flat bottoms and possessed glass covers ground to fit. The dishes were placed on a levelling table in a refrigerator until the gelatine had set. After the dishes with their gelatine had been weighed, a measured amount of water or of the desired solution was poured over the top of the gelatine, the covers replaced and the dishes placed in a refrigerator. At the end of the chosen interval of time the liquid was poured into another dish, the surface of the gelatine carefully dried with filter paper, the cover replaced and the dish weighed. After each weighing, the same liquid was returned to the gelatine. A reference to the tables will show that duplicates by this method gave a very small amount of variation. The numbers (1 and 2) at the heads of the column in the experiments marked "dishes" refer each to readings from one dish.

It will be noted that the amounts are always reduced to grams

per gram of dry weight of gelatine. It may be said first of all that the same ratios hold whether the unit of measurement was a given number of disks, a dish of gelatine of the size and kind referred to above or the unit that appears in the tables. The methods for determining the amount of dry weight of gelatine, of course, varied according to the salts included. The final dry weight of the mixture could naturally not be taken because of the passage of salts into and out of the gelatine. In all cases chemical analysis was resorted to, but since the reduction of the results to grams per gram of dry weight of gelatine never changed the ratio values enough to make any difference in the conclusions, the details of the chemical analysis will be omitted. The analyses were undertaken to find any possible difference in the ratios that might exist. A solution of 50 c.c. does not contain exactly 50 c.c. of water; consequently, in order to insure a constant water-content for all the samples, a small correction was made when necessary in the amount of solution added, so that all water-contents might be the same at the start. The entire water and evaporation history of every sample was identical from beginning to end of the experiment.

EFFECT OF HEAT ON THE IMBIBITION OF WATER BY GELATINE.

Some confusion exists in the literature over several points which have to do with facts which are necessary to discussions of theory. For example, Taylor,[4] interpreting Hofmeister, says of elastic jellies: "The quantity of liquid which can be taken up reaches a maximum, which depends on the gel, on the liquid, on the temperature and on the viscosity of the liquid. There is always contraction and always evolution of heat, from which, according to le Chatelier's theorem, heat will hinder or diminish imbibition, while cold and pressure will favor it." On the other hand, Fischer,[5] in his work with gelatine, attributes the "marked absolute difference in the amount of swelling" between various experiments to the difference in temperature which existed when all other conditions were identical, the gelatine which showed the greatest swelling being at the highest temperature. MacDougal,[6] working with a mixture of agar, bean

[4] Taylor, W. W., "The Chemistry of Colloids." New York, 1915, p. 155.
[5] Fischer, Martin H., "Œdema." New York, 1910.
[6] MacDougal, D. T., Proc. Soc. Exp. Biol. and Med., XV, 48–51. 1917.

protein and nutrient salts, draws from the results of his experiments the following conclusion: "The swelling of biocolloids is seen to increase in initial velocity and total amount to a maximum between 39° C. and 46° C. in the salted mixture and to 46° C. in the unsalted."

I have measured the rate of imbibition of water by gelatine at three different temperatures and have endeavored to find the[7] maximum water-content of the gelatine at the various temperatures. In trials of five hundred pieces, which included various sizes and thickness, and gelatine in various initial conditions of water-content, I found that, without a single exception, the higher the temperature (of course, within the limits where gelatine exists as a jelly) the greater the rate of imbibition and the greater the maximum at the point of apparent equilibrium. Table XVI presents a fair sample of the results which were obtained. Furthermore, when the temperature of imbibing gelatine was raised, its rate was always increased.

The statement above quoted from Taylor does not, then, stand the test of experiment. There may be more than one reason why this is so.

Le Chatelier's theorem may be stated briefly as follows:[8] "If we heat a chemical system, at constant volume, then there occurs a displacement of the state of equilibrium, and in that direction toward which the reaction advances with absorption of heat. If we compress a chemical system at constant temperature, there follows a displacement of the equilibrium in that direction which is associated with a diminution of volume."

Measurements have been made by so many workers that there can be no doubt about the fact that the uptake of water by gelatine is accompanied by evolution of heat and decrease of total volume (water plus gelatine).

If we decide to take it for granted that the mixture, water plus gelatine jelly, constitutes a "chemical system," then the first obvious thing to determine is whether or not we are dealing with an equilibrium phenomenon. To quote again from Nernst[9]: "Moreover, it requires great precaution before one can regard

[7] The value of this as an approximation is discussed later.

[8] Nernst, W., "Theoretical Chemistry." Trans. by Palmer. New York, 1895.

[9] Nernst, *loc. cit.*, p. 356.

a system as actually having arrived at a state of equilibrium. For the observation that no material change can be observed, even after a lapse of quite a long time, is by no means always sufficient."

In regard to this same subject, Washburn[10] says: "False equilibria are sometimes met with, due to various causes, such as * * * slow diffusion of one or more of the substances involved * * * In order to make sure the equilibrium should be approached from both directions."

In my experiments, apparent equilibria were attained at various temperatures, that is, the gelatine jelly ceased to gain in weight a measurable amount in forty-eight hours, in the presence of water. Whenever the temperature of such an apparent equilibrium was raised, the gelatine took up more water, but a lowering of the temperature caused neither a loss nor a gain of water. Consequently, the supposed equilibrium cannot be approached from "both directions."

Furthermore, it is a well-known fact that[11] "* * * all experimental measurement has shown that the velocity with which a chemical system strives to reach its state of equilibrium increases enormously with the temperature." Now in my experiments a rise of temperature always caused a marked increase in the rate of water uptake and a lowering of temperature a corresponding decrease in rate. This, when considered in the light of the known heat relations of imbibition and le Chatelier's theorem, is another bit of evidence that equilibria observed at the respective temperatures are only apparent ones.

Two important facts have a bearing upon this matter, the one that the diffusion of water through gelatine jelly is known to be relatively slow and the other that rate of diffusion always increases with temperature. After obtaining the apparent equilibrium point with thin pieces of gelatine, I have numerous times cut the pieces into smaller fragments and obtained an increase within a few hours, showing that diffusion of water into the interior had not been completed. It is impossible to continue any given experiment for more than two weeks above 25° C., or four weeks at 10°–20° C., because of bacterial infection. The

[10] Washburn, E. W., "Principles of Physical Chemistry." New York, 1915, p. 279.

[11] Nernst, *loc. cit.*, p. 568.

difficulty of sterilizing the gelatine itself without changing its constitution by heat or altering its tendency to absorb water by the addition of a sterilizing agent seems unsurmountable at present. Consequently, it is not now possible to make tests to show whether or not any given sizable piece of gelatine will become completely dispersed in water at temperatures below 25° C., but it is evident that some of the gelatine passes from the surfaces and becomes dispersed in the water. A very appreciable amount of gelatine is always obtained when the water which has surrounded pieces of gelatine for any length of time is evaporated to dryness.

So the evidence all goes to show that gelatine takes up water to at least nearly unlimited amounts at temperatures from 10° to 30° C. when given unlimited time—that there is no temperature below the point of liquefaction of gelatine where a true point of equilibrium is reached within less than two weeks. Thus the fact that heat favors imbibition in gelatine offers no contradiction to the laws of thermodynamics. Indeed, considering the firm basis on which thermodynamic laws are founded, it would seem more logical to argue in the opposite direction from the experimental data, and to say that since heat favors imbibition in an exothermic reaction, then there is no true point of equilibrium measured within the range of temperatures used. Of course, as soon as the jelly begins to assume the liquid state then the action becomes endothermic, and here we are introduced to the riddle of another equilibrium point.

So far as biological phenomena and their interpretation are concerned, the apparent equilibria may usually be treated as real ones, because all important biological phenomena take place within a limited time; it is only when we try to make predictions from theoretical reasoning that caution must be observed.

EFFECT EXERTED ON THE IMBIBITION OF WATER, OF INCLUDING VARIOUS SOLUTIONS WITHIN GELATINE JELLY.

Ever since the time of Hofmeister, it has been known that the imbibition of gelatine can be greatly changed by the addition of acids, bases or salts to the water which is being imbibed, and many theories have been advanced based on Hofmeister's series. For example, Taylor says: "Arranged in order of increasing effectiveness in promoting imbibition, the series is sodium-sul-

phate, tartrate, citrate, acetate; alcohol, glucose, cane sugar; (water) chlorides-potassium, sodium, ammounium, sodium chlorate, nitrate, bromide; * * * The substances before water hinder imbibition * * * while the salts after favor imbibition. The order is again the lyotrope series which we have come across so often. As already seen, the modulus of elasticity is affected by salts in the lyotrope order; this is the same series in the reverse order. As was to be expected, a substance which renders a gel more easily deformed (reduction of E) will favor imbibition."

Now this reasoning is based on the assumption that the salts affect the gelatine by their presence in it. Since the salts quickly become disseminated through the gelatine by the processes of diffusion and adsorption, it seems reasonable to suppose that the same effect might be had if the salts are made up into the gelatine and the mixture allowed to absorb water. Indeed, it must be so unless such reasoning as that given above is to be modified. I have undertaken a series of experiments to test this matter and the results have been most unexpected.

Tables V–XIII show that if the salts belonging to the class which increase imbibition are made up in solution in the gelatine and the resulting jelly allowed to absorb water, the imbibition is also increased; and that when salts which belong to the class that decrease imbibition are made up in the gelatine and this resulting jelly allowed to absorb water that imbibition is increased. All the salts tried in the experiments increase the imbibition of water if they are made up in the gelatine itself.

TABLE V.

Imbibition per Hour per Gram of Dry Gelatine of: (A) 28 per cent. Gelatine Plus 72 per cent. Water, Placed in Water; (B) 28 per cent. Gelatine Plus 72 per cent. M Ammonium Chloride, Placed in Water. Jellies not Allowed to lose Water After Being Made up. Ratios Calculated from Averages Appear in Parentheses Below Numbers.

Time	A		B	
	1	2	1	2
1st to 4th hr	0.918	0.923	1.470	1.474
		(1.00)		(1.60)
4th to 7th hr	0.332	0.334	0.515	0.512
		(1.00)		(1.54)
7th to 12th hr	0.059	0.065	0.105	0.110
		(1.00)		(1.74)

Now it will be noted that when these substances were made up in the gelatine that the mixture stood at 50°–60° C. over a water-bath for about 15 minutes. Consequently, it is possible that a chemical change occurred between gelatine and salt which might not have taken place if the substances had been inserted into the gelatine at a lower temperature. Therefore, it seemed

TABLE VI.

Imbibition per Hour per Gram of Dry Gelatine of Jellies of the Following Compositions: (A) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing Water; (B) 28 per cent. Gelatine Made up With 72 per cent. M Sodium Chloride, Imbibing Water; (C) 28 per cent. Gelatine Made up With 72 per cent. M Sodium Chloride, Imbibing Water. Jellies Not Allowed to Lose Water After Being Made up. Ratios Calculated from Averages of the Duplicates Appear in Brackets Beneath the Numbers. Disks.

Time	B		B		C	
	1	2	1	2	1	2
1st to 3rd hr.	0.742	0.746	1.161	1.153	1.229	1.239
	(1.0)		(1.6)		(1.7)	
3rd to 6th hr.	0.755	0.760	0.850	0.852	1.345	1.350
	(1.0)		(1.1)		(1.8)	
6th to 18th hr.	0.225	0.235	0.261	0.273	0.453	0.453
	(1.0)		(1.2)		(2.0)	
18th to 42nd hr.	0.044		0.045	0.057	0.124	
	(1.0)		(1.2)		(2.8)	

TABLE VII.

Imbibition per Hour per Gram of Dry Gelatine of Jellies of the Following Compositions: (A) 28 per cent. Gelatine Made up With 72 per cent. Water, Placed in Water; (B) 28 per cent. Gelatine Made up With 72 per cent. Water, Placed in M Cane Sugar; (C) 28 per cent. Gelatine Made up With 72 per cent. Water, Placed in M/2 Cane Sugar; (D) 28 per cent. Gelatine Made up With 72 per cent. M Cane Sugar, Placed in Water; (E) 28 per cent. Gelatine Made up With 72 per cent. M/2 Cane Sugar, Placed in Water. Jellies Not Allowed to Lose Water After Being Made up. Ratios Calculated from the Averages of the Duplicates Appear in Brackets Below Numbers. Disks.

Time	A		B		C		D		E	
	1	2	1	2	1	2	1	2	1	2
1st to 2nd hr.	0.256	0.248	−0.041	−*0.037	0.113	0.113	0.291	0.388	0.314	0.314
2nd to 3rd hr.	0.121	0.127	−0.014	−0.014	0.073	0.075	0.200	0.194	0.153	0.151
3rd to 4th hr.	0.076	0.080	−0.012	−0.012	0.034	0.042	0.145	0.145	0.118	0.125

* Negative sign indicates decrease in weight.

advisable to make up the gelatine in the usual proportions (20 of gelatine to 50 of water), allow it to set and then to absorb all of a small quantity of a solution of the substance whose presence is desired in the gelatine jelly. The gelatine was made up as has been described on page 324, 10 c.c. of liquid gelatine being transferred to each small dish by means of a pipette, all of the

TABLE VIII.

Imbibition per Hour per Gram of Dry Gelatine of Jellies of the Following Compositions: (A) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing Water; (B) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing 2M Ethyl Alcohol; (C) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing M Ethyl Alcohol; (D) 28 per cent. Gelatine Made up With 72 per cent. 2M Ethyl Alcohol, Imbibing Water; (E) 28 per cent. Gelatine Made up With 72 per cent. M Ethyl Alcohol, Imbibing Water. Jellies Not Allowed to Lose Water After Being Made up. Ratios Calculated from the Averages of Duplicates Appear in Brackets Below Numbers. Disks.

Time	A		B		C		D		E	
	1	2	1	2	1	2	1	2	1	2
1st to 2d hr.	0.247	0.248	0.097.	0.097	0.171	0.173	0.344	0.347	0.284	0.289
	(1.00)		(0.39)		(0.69)		(1.39)		(1.16)	
2nd to 3rd hr.....	0.128	0.131	0.054	0.051	0.072	0.072	0.155	0.155	0.151	0.150
	(1.00)		(0.41)		(0.055)		(1.19)		(1.06)	
3rd to 4th hr	0.082	0.088	0.043	0.046	0.062	0.066	0.097	0.105	0.088	0.091
	(1.00)		(0.53)		(0.75)		(1.19)		(1.06)	

TABLE IX.

Imbibition per Hour per Gram of Dry Gelatine of Jellies of the Following Compositions: (A) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing Water; (B) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing 2M Sodium Citrate; (C) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing M Sodium Citrate; (D) 28 per cent. Gelatine Made up With 72 per cent. 2M Sodium Citrate, Imbibing Water; (E) 28 per cent. Gelatine Made up With 72 per cent. M Sodium Citrate, Imbibing Water. Jellies not Allowed to Lose Water After Being Made up. Ratios Calculated from the Averages of the Duplicates Appear in Brackets Below the Numbers. Dishes.

Time	A		B		C		D		E	
	1	2	1	2	1	2	1	2	1	
1st to 2nd hr.	0.200	0.206	0.032	0.031	0.132	0.134	0.349	0.355	0.287	0.289
	(1.00)		(0.16)		(0.65)		(1.73)		(1.42)	
2nd to 3rd hr.	0.111	0.117	0.030	0.035	0.075	0.078	0.209	0.200	0.191	0.181
	(1.00)		(0.29)		(0.66)		(1.80)		(1.63)	
3rd to 4th hr.	0.091	0.097	0.036	0.045	0.078	0.082	0.170	0.176	0.165	0.170
	(1.00)		(0.43)		(0.85)		(1.84)		(1.79)	

TABLE X.

Imbibition per Hour per Gram of Dry Gelatine of Jellies of the Following Compositions: (A) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing Water; (B) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing 2M Sodium Tartrate; (C) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing M Sodium Tartrate; (D) 28 per cent. Gelatine Made up With 72 per cent. 2M Sodium Tartrate, Imbibing Water; (E) 28 per cent. Gelatine Made up With 72 per cent. M Sodium Tartrate, Imbibing Water. Jellies Not Allowed to Lose Water After Being Made up. Ratios Calculated from Averages of the Duplicates Appear in Brackets Under the Numbers. Dishes.

Time	A		B		C		D		E	
	1	2	1	2	1	2	1	2	1	2
2 hrs.....	0.548	0.569	0.356	0.361	0.475	0.481	0.735	0.739	0.654	0.664
	(1.00)		(0.64)		(0.96)		(1.33)		(1.18)	

TABLE XI.

Imbibition per Hour per Gram of Dry Gelatine of Jellies of the Following Compositions: (A) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing Water; (B) 28 per cent. Gelatine Made up With 72 per cent. M/2 Sodium Sulphate, Imbibing Water; (C) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing M/2 Sodium Sulphate. Jellies Allowed to Lose Water Until Constant Weight at Air Temperature was Reached Before Imbibition Began. Ratios Calculated from Averages of Duplicates Appear Beneath Numbers. Disks.

Time	A		B		C	
	1	2	1	2	1	2
3 hrs.....	0.572	0.563	0.903	0.911	0.432	0.450
	(1.00)		(1.60)		(0.8)	

TABLE XII.

Imbibition per Hour per Gram of Dry Gelatine of Jellies of the Following Compositions: (A) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing Water; (B) 28 per cent. Gelatine Made up With 72 per cent. M Sodium Sulphate, Imbibing Water; (C) 28 per cent. Gelatine Made up With M/2 Sodium Sulphate, Imbibing Water; Jellies Allowed to Lose Water Until Constant Weight at Air Temperature was Reached Before They were Placed in Water. Ratios Calculated from Averages of Duplicates Appear in Brackets Beneath Numbers. Disks.

Time	A		B		C	
	1	2	1	2	1	2
2 hrs.....	0.641	0.649	0.207	0.199	0.926	0.934
	(1.0)		(3.1)		(1.4)	

gelatine allowed to set and then 3 c.c. of the appropriate solution placed over the surface. The dishes were tightly covered and allowed to stand at about 12° C. for twenty-four hours, at the end of which time all of the solutions had been absorbed by the gelatine. The disks were then removed from the dishes and allowed to lose water until constant weight was attained at air temperature. Drying was hastened by means of an electric fan. After all the disks had attained equal water-content, they were placed in dishes of distilled water, from which they were removed at stated intervals, dried and weighed for the increase in weight.

TABLE XIII.

Imbibition per Hour per Gram of Dry Gelatine of Jellies of the Following Compositions: (A) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing Water; (B) 28 per cent. Gelatine Made up With 72 per cent. M/2 Sodium Sulphate, Imbibing Water; (C) 28 per cent. Gelatine Made up With 72 per cent. M/5 Sodium Sulphate, Imbibing Water; (D) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing M/2 Sodium Sulphate; (E) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing M/5 Sodium Sulphate. Jellies Not Allowed to Lose Water After Being Made up. Ratios Calculated from the Averages of the Duplicates Appear in Brackets Below the Numbers. Dishes.

Hours	A		B		C		D		E	
	1	2	1	2	1	2	1	2	1	2
8 hrs.....	0.526	0.522	0.885	0.878	0.851	0.859	0.374	0.382	0.515	0.530
	(1.0)		(1.7)		(1.6)		(0.7)		(1.0)	

TABLE XIV.

Imbibition per Hour per Gram of Dry Weight of Gelatine from Gelatine Disks (28 per cent. Gelatine to 72 per cent. Water) which have Absorbed in the Cold Equal Volumes of the Following: (A) Distilled Water; (B) Molecular, Sodium Bromide; (C) Molecular, Ammonium Chloride; (D) Molecular, Sugar; (E) One-half Molecular, Sodium Citrate; (F) One-half Molecular, Sodium Sulphate, all Imbibing Water. Disks were Air Dry at Beginning of Experiment. Ratios Calculated from the Averages of the Duplicates Appear in Brackets Below Numbers.

Hours	A		B		C		D		E		F	
	1	2	1	2	1	2	1	2	1	2	1	2
0–2.....	0.713	0.718	0.900	0.906	0.799	0.815	0.663	0.631	0.973	0.949	0.930	0.922
	(1.00)		(1.26)		(1.13)		(0.90)		(1.34)		(1.29)	
2–4.....	0.306	0.298	0.372	0.372	0.319	0.309	0.416	0.390	0.579	0.569	0.410	0.414
	(1.00)		(1.23)		(1.04)		(1.33)		(1.90)		(1.36)	
4–23....	0.113	0.110	0.115	0.119	0.115	0.115	0.089	0.111	0.123	0.129	0.104	0.111
	(1.00)		(1.05)		(1.04)		(0.901)		(1 12)		(0.96)	

Table XIV shows an increase in imbibitional rate for the first four hours in the case of all the substances used, with the exception of cane sugar, which is irregular in its behavior. Sodium citrate and sodium sulphate, substances which decrease the imbibition of gelatine when in the external solution, cause the greatest increase in rate here. For the next nineteen hours the rates became nearly equal for all the substances. Subsequent evaporation of the various liquids surrounding the gelatine showed that much of the material that had been included in the gelatine diffused out into the surrounding water and so later results could not be expected to agree with the earlier ones.

Table XV gives the results obtained from a similar experiment when the gelatine used for imbibition was not allowed to lose water by evaporation after it was made up. This time 5 c.c.

TABLE XV.

Imbibition per Hour per Gram of Dry Weight of Gelatine from Disks of Jelly (28 per cent. Gelatine to 72 per cent. Water) Which Have Absorbed in the Cold Equal Volumes of the Following: (A) Distilled Water; (B) Molecular, Sodium Bromide; (C) Molecular, Sodium Chloride; (D) Molecular, Sugar; (E) One-half Molecular, Sodium Citrate; (F) One-half Molecular Sodium Sulphate; (G) One-half Molecular, Hydrochloric Acid, all Imbibing Water. No Evaporation of Water Took Place from the Gelatine. Ratios Calculated from the Averages of Duplicates Appear in Brackets Below Numbers.

Hours	A		B		C	
	1	2	1	2	1	2
0-1	0.23	0.23	0.35	0.35	0.35	0.35
	(1.00)		(1.52)		(1.52)	
1-3	0.12	0.10	0.14	0.14	0.11	0.13
	(1.0)		(1.3)		(1.1)	
3-27	0.29	0.027	0.041	0.041	0.039	0.043
	(1.00)		(1.46)		(1.46)	
27-51	0.0059	0.0059	0.0076	0.0076	0.0060	0.0068
	(1.00)		(1.29)		(1.08)	

Hours	D		E		F		G	
	1	2	1	2	1	2	1	2
0-1	0.34	0.33	0.47	0.51	0.41	0.36	0.34	0.35
	(1.45)		(2.13)		(1.65)		(1.50)	
1-3	0.14	0.13	0.17	0.18	0.14	0.15	0.11	0.11
	(1.2)		(1.6)		(1.3)		(1.0)	
3-27	0.030	0.025	0.040	0.039	0.046	0.042	0.030	0.034
	(0.98)		(1.43)		(1.57)		(1.14)	
27-51	0.0030	0.0026	0.0072	0.0077	0.0076	0.0080	0.0053	0.0059
	(0.47)		(1.27)		(1.32)		(0.95)	

of the liquid gelatine were placed in the small cylinders, and as soon as the material had set, 1 c.c. of each was spread evenly over the top of the disks. After the solution had been completely absorbed the disks were allowed to stand for twenty-four hours and then water was poured over the top without disturbing the position of the disks in their dishes (for details of this method see page 324). These results agree with those given in Table XIV. Thus it is seen that the evaporation to dryness of the gelatine does not influence the effect of these substances on imbibition.

TABLE XVI, PT. I.

Imbibition per Hour per Gram of Dry Gelatine for Gelatine Jelly (28 per cent. Gelatine, 72 per cent. Water) Under Three Different Temperature Conditions. Ratios Calculated from the Averages of Duplicates Appear in Parentheses Beneath Numbers. Disks.

Hours	10° C.			20° C.		32° C.		
	No. 13	No. 14	No. 20	No. 10	No. 12	No. 5	No. 7	No. 8
0-1	0.70	0.69	0.63	0.93	0.87	1.45	1.47	1.49
		(1.00)		(1.34)			(2.19)	
1-3	0.38	0.33	0.28	0.59	0.54	0.63	0.59	0.67
		(1.00)		(1.71)			(1.91)	
3-8	0.19	0.13	0.15	0.27	0.26	0.43	0.40	0.38
		(1.00)		(1.65)			(2.50)	
8-20	0.06	0.05	0.05	0.10	0.11	0.18	0.20	0.17
		(1.0)		(2.0)			(3.7)	
20-26	0.03	0.01	0.03	0.03	0.03	0.12	0.10	0.11
		(1.0)		(1.3)			(4.7)	
26-51	0.01	0.01	0.01	0.03	0.03	0.04	0.03	0.05
		(1.0)		(3.0)			(4.0)	
51-67	0.007	0.007	0.007	0.03	0.03	0.04	0.03	0.04
		(1.0)		(4.0)			(5.0)	
67-90	0.007	0.007	0.010	0.01	0.01	0.04	Bacteria	Bacteria
		(1.0)		(1.4)				
90-113	0.000	0.000	0.000	0.005	0.004	Bacteria		
113-137	0.000	0.000	0.000	0.000	0.000			
137-152	−0.011	−0.005	0.000	0.000	0.000			
152-200	−0.010	−0.01	0.000	Bacteria				

TABLE XVI, PT. II.

Water-content of Material Used in Table XVI, Pt. I, at the Points of Approximate Equilibria.

	10° C.			20° C.		32° C.		
	No. 13	No. 14	No. 20	No. 10	No. 12	No. 5	No. 7	No. 8
	3.93	3.83	4.20	6.14	6.02	10.66	8.62	
		(1.00)		(1.5 3)		.42	(2)	

All of the experiments with substances from the Hofmeister series show that it is necessary to exercise great caution in drawing conclusions concerning biological behavior from experiments on the imbibition of gelatine. Obviously, in the light of this work, it is absurd to conclude that the accumulation of sodium citrate in the protein jelly of living tissue causes a decrease in its imbibitional capacity because gelatine absorbs less water from a solution of sodium citrate than from water. It may be seen that caution is needed likewise in drawing conclusions regarding the theory of imbibition itself, when the passage quoted above (p. 329) from Taylor regarding the relation of the modulus of elasticity to imbibition is viewed in the light of the results I have here obtained. *It is, then, not safe to draw conclusions regarding the effect which substances within a jelly exert upon its imbibitional capacity, when the evidence for such a conclusion lies in the known effect of an external solution of the same substance on that same or other jellies.*

The facts brought out in this paper, and a former one, relating to the effect of evaporation, of heat, and of salt solutions on the imbibition of water by gelatine offer several suggestions for a theory for the mechanism of the entrance of water into gelatine, but it seems to me that the time is not yet ripe for the formulation of such a theory, especially since new facts are appearing almost daily from various sources.

SUMMARY.

1. Within the temperature range 10°–35° C. heat favors the imbibition of water by gelatine, although the reaction is exothermic. This is not a contradiction of Le Chatelier's theorem regarding the effect of heat on equilibrium in chemical systems, because the reaction reaches only an apparent and not a true equilibrium.

2. When dry gelatine is made up to a jelly with any of the solutions mentioned below, instead of with water, or when gelatine jelly contained 72 per cent. water is allowed to completely absorb one-fifth to three-tenths its own volume of these solutions at 10°–35° C., the imbibitional properties of the gelatine are so changed that the rate of uptake of water is increased. These solutions are: molecular ammonium chloride; molecular sodium chloride; molecular sodium bromide; twice molecular, and molec-

ular ethyl alcohol; twice molecular, and molecular sodium citrate; twice molecular, and molecular sodium tartrate; molecular, and half molecular sodium sulphate. When dry gelatine is made up to a jelly with water and placed in these solutions and the rates of imbibition compared with the rate in distilled water, the results are found to agree with those of Hofmeister. That is, the rate of imbibition of water by gelatine jelly is greater for ammonium chloride, sodium chloride, and sodium bromide than for distilled water, and less for ethyl alcohol, sodium citrate, sodium tartrate, and sodium sulphate than for distilled water.

3. Therefore, it is not safe to draw conclusions regarding the effect which substances within a jelly exert upon its imbibitional capacity, when the evidence for such a conclusion lies in the known effect of an external solution of the same substance on that same or other jellies. All theories based on such assumptions are open to criticism. This applies to the theories involving the physico-chemical causes of the effect of the materials on the gelatine itself, as well as those concerning physiological phenomena.

A Review of Electric Arc Welding. J. A. SEEDE. (*General Electric Review*, vol. 21, No. 13, p. 881, December, 1918.)—As originally practised, arc welding was a rather crude process consisting in drawing an arc about an inch long from a carbon electrode to the work, and feeding the welding in the form of a welding rod similar to the ordinary soldering process. The work produced was very rough and the process was mainly used in such work as filling blowholes and other defects in castings and forgings, and building up metal removed through errors in workmanship.

Later, better results were obtained by drawing the arc from the welding metal, doing away with the carbon electrode. The new process proved considerably more difficult than the old one, as the arc was considerably shorter, having approximately one-half the voltage drop, and therefore more sensitive and more difficult to maintain so as to produce good results. Despite this and other difficulties steady progress was made, and metallic electrode welding soon began to be used for such important work as repairs on boilers of locomotives, vessels and for many other applications requiring comparatively high tensile strength with some ductility. It may be prophesied, without fear of contradiction, that the near future will bring many applications of arc welding in an ever-expanding field.

Crisis in the American Potash Industry. ANON. (*U. S. Geological Survey Press Bulletin,* No. 397, February, 1919.)—The present is a critical time for the potash industry recently established in the United States, according to H. S. Gale, of the U. S. Geological Survey, Department of the Interior. Prior to the war this country used more than a million tons (gross weight) of potash salts each year, and it has been supposed that the cutting off of a large part of this supply was a keen deprivation, particularly to the farmer, by whom it was used for fertilizer. This foreign supply has not been available during the war, and with much energy and enthusiasm a domestic production equivalent to about one-fourth the former importation has been built up. Now, however, it is unexpectedly disclosed that there is little or no market for potash either at the high prices that have prevailed or even at a considerably lower price. No satisfactory explanation of this situation seems to be offered.

Approximately 100,000 tons (gross weight) of potash salts, produced in Nebraska in 1918, are reported as lying in storage warehouses, distributed throughout the southeastern states, which is the region where potash is principally consumed. This is of the same quality that was used in 1917 and is immediately available to the fertilizer manufacturer or the farmer. Potash of other sorts from various sources is also reported unsold, though in smaller quantities. As this surplus represents approximately half the relatively small domestic production and as potash from foreign sources has not been available during the year, it is difficult to explain this apparent lack of interest in the present small domestic supply.

Potash is a term commonly used in referring to the miscellaneous materials carrying potassium which are used or valued chiefly for the potassium contained in them. In 1913, the last year before the war, there was imported into the United States 1,092,588 short tons (gross weight) of the miscellaneous potash-bearing materials, equivalent to 270,720 short tons of "pure" or "actual" potash. This includes the figures for the following salts: Kainite, manure salts, chloride (muriate), sulphate, bicarbonate, bitartrate (argol), bitartrate (cream of tartar), carbonate (crude, crude black salts and refined), caustic chlorate, chromate, bichromate, ferrocyanide (yellow prussiate), ferricyanide (red prussiate), iodide, nitrate (saltpeter, crude and refined), permanganate and Rochelle salts.

Since 1913 the imports of these substances have greatly decreased, until during 1916 and 1917 the total gross weight of potash salts imported was only about 25,000 short tons, containing about 8000 tons of "actual" potash. By far the greater part of potash formerly imported came from Germany, but some of the substances named in the list have come from other places and were received even during the war.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

ANNUAL REPORT OF THE DIRECTOR.

[ABSTRACT.]

THE functions of the National Bureau of Standards are the development, construction, custody and maintenance of reference and working standards and their intercomparison, improvement and application in science, engineering, industry and commerce.

When the United States entered the war this service already possessed exceptional facilities, equipment and personnel for exact scientific research in physics, chemistry and engineering. This enabled it to take up promptly many important military researches. The bureau, indeed, coöperated with the army and navy, prior to the war, in the development of radio apparatus, in developing automatic devices for recording battleship target practice, the design of optical systems for submarine periscopes and other purposes, the testing of all kinds of supplies, and the furnishing of data in electricity, heat, light, engineering and chemistry.

In anticipation of demands the bureau before the war had begun special researches known to be required. The urgency of many of these problems was not realized even by those in close touch with the situation. The absolute cutting off of the optical-glass supply, the failure of the linen supply, the total lack of ship chronometers and the necessary uses of light alloys are examples. The rapidity with which the military researches were prosecuted is gratifying, as is the fine spirit of coöperation exhibited. The one thought has been the fullest aid where science could help win the war. The expansion of the bureau to meet the new demands engaged the most serious attention of the staff, and men and facilities were freely furnished for military work. Practically every section of the bureau's regular organization has had military problems of the most pressing nature submitted to it, and invaluable service has been rendered.

The recent expansion of the bureau has been on lines vital to the success of the war. It is interesting to note, however, that

* Communicated by the Director.

many of these lines are of essential value to our industries in peace. The need for the national provision for master-gauge standardization was only realized by those in close touch with such work. The establishment of a gauge-standardization laboratory has proven an important aid to the mechanical industries. The accurate dimensioning of the functioning parts of mechanisms will permit extending the American system of manufacturing interchangeable parts to its maximum usefulness. The importance of nation-wide standardization has long been known, but the practical working out of such standardization is best met by a national laboratory such as the Bureau of Standards. The same principle holds for all the technologies and special branches of physics. The researches now being conducted for war purposes will prove of inestimable permanent value for the general welfare.

AERONAUTICAL RESEARCH.

During the year scientific problems in nearly all branches of aeronautics have been investigated by the bureau, comprising material, design, power sources and technical data. The work is being done in coöperation with the National Advisory Committee for Aeronautics and the military departments of the Government. The primary researches include the development of systems of laboratory tests of all details of airplane design, such as materials, construction, efficiency of form, motor performance, the efficiency of lubrication, carburetion, ignition, choice of fuel, propeller and plane performance, measuring instruments and the appliances and physical constants required throughout for control. These and other pertinent airplane investigations were taken up in the laboratories of the bureau under closely simulated service conditions, embracing such factors as air pressure and air movement, temperature, vibration, humidity, etc.

The engineering testing and investigation covered airplane parts, the use of spruce in airplane construction and mahogany for propellers, the development of instruments for measuring the tension in airplane cables, study of shock-absorbing wheels for airplanes and sea planes, and many others.

A unique feature of the airplane-research program now under way is the development, in connection with the National Advisory Committee for Aeronautics, of a system of free-flight tests made in normal flying as actually practiced by army aviators. Here

the problem is to develop a series of autographic instruments which during free flight will furnish the primary data for a scientific study of the theory on which airplanes are designed. The six autographic instruments have been designed at the laboratories of the Bureau of Standards, and three have been completed. These will furnish, without any attention from the aviator, a continuous graphic time record during the entire period of flight, showing the engine torque, revolutions per minute, propeller thrust, plane speed, angle of attack and inclination with horizon.

The bureau's aeronautical instrument laboratory had done fundamental work on the theory of the altimeter and had been testing such instruments for several years before the war began. The staff was promptly increased and now consists of about thirty-five men. The work of this section is to discover sources of error or improvement in the instruments on which aviators depend for aerial navigation, scouting, fighting and bombing, and to develop standard testing methods. In one instance the bureau's tests caused the rejection of 5000 altimeters.

The bureau is now engaged in further researches to promote the operative efficiency of these devices. It has been in close touch with the manufacturing industries in order to make these instruments more reliable and to guard especially against errors due to low temperature, vibration and centrifugal effects occurring during the banking of planes. New kinds of dynamometers, for example, have been designed.

Information gained by this section has been given in lectures to aviation officers supplemented by laboratory demonstrations. Many technical conferences with those concerned have been the means of furnishing a great deal of information. Reports have been made covering many aspects of aviation instruments. The bureau furnished the data upon which the specifications for aviation instruments were drawn for the Signal Corps. The bureau's experts visit the factories and the factory experts visit the bureau for coöperation in overcoming errors and improving output. The bureau staff has not only conducted theoretical and experimental researches in the laboratory under simulated service conditions, but its experts have also studied the instruments in actual flight, including air-speed meters and dynamometers.

The work of aeronautical research required special attention

to be given to aerodynamics. A special laboratory for this purpose was built, containing a wind tunnel provided with a wind stream maintained by a 9-foot propeller mounted directly upon the shaft of a 100-horsepower motor. Air speeds of 90 miles were obtained in this tunnel. The purpose of the wind tunnel is to test measuring instruments used on airplanes, to study the design of airplane parts, stabilizing control devices, the efficiency of stream lines, plane sections, etc. For example, the tests included models of airplane and dirigible air-speed indicators, bomb-dropping devices, characteristics of aerial bombs in the wind tunnel and the like. Incidental uses of the wind tunnel have been made in the study of wind stresses on telephone, telegraph and electric-power wires coated with ice and the efficiency of ventilators.

AIRPLANE POWER PLANTS.

At the beginning of the fiscal year research on airplane motor problems, such as the radiator and spark plug design problem, was already under way; this work has greatly expanded and many research problems on aeronautic power plants and accessories have been taken up. An altitude laboratory has been built and put in operation, in which aeronautic engines can be tested at the atmospheric pressures and temperatures encountered at high altitudes under service conditions in warfare. One hundred and twenty sets of observations have been made and results of great importance secured. A dynamometer laboratory has been constructed and equipped with a 400-horsepower dynamometer. This has been of special service in the spark-plug and lubrication investigations.

The effective operation of airplanes at the front depends upon perfecting the essential functioning parts of the engine and also upon the maintenance of the most efficient adjustment of carburetor, lubrication, etc., at all altitudes. The bureau's work has covered both the design and the working characteristics. A study has been made in particular of spark plugs. Fifty compositions of porcelain were made and studied, and the porcelain which showed the highest performance was selected. In operating the spark plug it became essential to study the various types of magnetos, and favorable results have been obtained. The results of the ignition investigations are being utilized by manufacturers and the various military bureaus.

The bureau was enabled to locate serious faults with the carbureting systems when operated at high altitudes, and, as a result, a radical improvement may now be expected in this equipment.

More than 100 radiator designs for airplane use were tested out. New features are to be undertaken with a view to the most effective design. Valuable results have been obtained in the investigation of lubricants, and since the lubricating problem is a vital factor in airplanes, these results are important in that field. Tests have been made of various models of the Hispana-Suiza and Liberty motors as to performance, durability, lubrication, etc.

STANDARDIZATION OF MUNITIONS MASTER GAUGES.

A particularly urgent need upon our entrance into the war was for an adequate supply of standardized master gauges for making munitions. Such gauges are a fundamental requisite. The bureau had already begun such gauge work in its weights and measures laboratories. A matter so vital to the increase in munitions called for by the declaration of war caused the bureau to anticipate this need, and it actively prepared to take up the work to meet the demand to come from the military departments and munitions industries. The rapid organization of the technical and mechanical force to handle the great variety of gauges required for producing munitions has been a fine achievement; its success is unqualified. The bureau's chief expert in charge has entered the military service to coöperate in this work of gauge testing for the arsenals and munitions plants. Before the war only one member of the bureau staff was engaged in this work; at the close of the fiscal year a staff of 140 was busy in it. A branch gauge laboratory has been established in New York City, and laboratories in Cleveland, Ohio, and Bridgeport, Conn., are to be opened soon.

OPTICAL INSTRUMENTS AND LIGHT.

The bureau's optical staff has rendered most important service in connection with the war. This includes the manufacture of optical glass, the design and construction of new optical instruments for military purposes, the testing of such instruments and others purchased for war use, and also highly technical work on radiometry, spectroscopy and colorimetry.

The technical staff in optics has aided in the design of optical systems for periscopes, airplane cameras, long-distance cameras, gun-sight telescopes, stadimeter telescopes, field glasses, etc. The bureau has especialy coöperated to bring about quantity production of the instruments essential to the army and navy. More than 2000 instruments and parts have been tested. These are mainly American instruments made of American optical glass. The high standard of perfection attained is a gratifying result of the active coöperation between the military departments, the bureau and the industries.

Closely related to the above are the applications of optical methods during the year to the measurement of the expansion of such materials as standard steel gauges, fused quartz and optical glass. The bureau has perfected instruments and methods for standardizing methods of turbidimetry, a new and important branch of measurement applicable, for example, to smoke, fog, dusty gases, muddy rivers, ocean turbidity, and the special cases of optical glass, crystals, opal and milk glass; in fact, wherever solid suspensions are an important factor. The industrial applications include tanning, dyeing, paper manufacture, a control of city water filtration, the regulation of the maximum smoke and dust permitted to be discharged into the atmosphere in the cities, and numerous others.

With the advent of the war foreign sources of optical glass were cut off, and, of course, no German glass could be obtained. The French and English needed every pound of their own production and were unable to meet their own requirements. The problem of producing glass of the kinds and qualities required for military purposes was a most serious one. The need for the most perfect obtainable binoculars, camera lenses, optical systems for periscopes, range finders, and optical glass for other purposes could scarcely be overstated, as in a very real sense such optical glass products are the eyes of the military services.

At the time we entered the war the bureau had been actively interested for several years in the problem of producing optical glass in the United States. It was believed that this country could be a producer of optical glass, and the bureau planned to do its part in stimulating such production, both by experiment and research and by the closest possible coöperation with the industries concerned. When we became a belligerent the problem was no longer

one of national pride or revenue or independence of foreign supplies. The production of optical glass in America became an acute, vital and immediate necessity. The bureau, therefore, promptly expanded its force and assigned the needed assistance to the existing glass section of the bureau, with instructions to develop the methods of producing optical glasses of all varieties required, on a commercial scale. The technical literature contained a sufficient variety of acceptable formulas, but little as to technique. Experiments were conducted by the bureau, and every detail of the manufacture was worked out by study of theory, by actual experiment and by the study of each factor affecting the optical quality of the glasses produced. The result was gratifying. The bureau has developed the types of optical glass required for military purposes in the war, and has produced them on a commercial scale. It is now supplying optical glass in quantities made in its own shops to be used for the manufacture of optical instruments. The glass is of excellent quality. The bureau also made the clay pots in which the glass was melted. Strangely enough, the problem of producing suitable clay pots for the purpose was one of the fundamental problems in quality production—one which had not been solved by private manufacturers. The bureau determined the clays suitable and the methods of making the glass pots. It actually produced the pots in the quantity required for its own work and furnished the industries with directions for making them.

The bureau has fully coöperated with all glassmakers in producing a supply adequate for war purposes.

Important investigations in radiometry have been made during the year. Standards of radiation in absolute measure were intercompared. Methods were developed for measurements required in the life tests of incandescent lamps. The effect of radiation on balloon fabrics was studied experimentally. The rising temperature of the fabric when exposed to solar radiation was measured, using the precision thermocouple. A small-size model balloon is now being used for this study. Extensive data have been obtained of the photo-electric sensitivity of molybdenite, in view of possible applications of these properties. The bureau's work on glasses for protecting the eyes from injurious radiations has been extended by gathering new data on the transmission of the invisible ultra-violet and infra-red radiations. The

bureau has furnished data on various phases of radiation for military applications.

MINE AND RAILROAD-TRACK SCALES.

The mine-scale work of the Bureau of Standards, for which Congress made special provision for a nation-wide investigation, is of special interest, in view of the need for maximum output of coal at the mines. Disputes over weighings cause strikes, loss of time and reduced output. The bureau experts were called upon, and they found the conditions wholly unsatisfactory. In one case a 2-ton scale was 616 pounds in error against the miner. Improper installation, faulty methods of weighing and errors were corrected and mines greatly improved. Indictments were found and fines imposed on the evidence of bureau experts. A general awakening and improvement have resulted, and the prevention of strikes and the renewed satisfaction of the miner have gone far to maintain conditions favorable to a maximum output of coal at the mines.

STANDARDIZATION OF TIMEPIECES.

The time laboratory of the bureau maintains a precision standard clock of the Riefler type, corrected from the noon signals from the Naval Observatory. The bureau's clock in a recent 54-day run exhibited remarkable accuracy, maintaining a constant rate within 0.15 of a second and a net change of rate during the 54 days of 0.01 of a second. The standard clock is connected electrically with the laboratories, which require precise time measurements.

SOUND AND ACOUSTICS.

An interesting feature of the bureau's work has been the development of its laboratory for the study of sound. This has been placed upon a practical basis during the year by the acquisition of much-needed equipment. The applications of acoustics to warfare have been quite important. These include elements in the problems of sound ranging and the detection of submarines, airplanes and enemy operations by acoustic methods. Devices have been perfected which analyze sounds into their components. A special study has been made in the sound laboratory of the photographic analysis of sound waves with particular reference to the improvement of airplane-engine mufflers.

ELECTRICAL RESEARCH AND TESTING.

The electrical work of the bureau is of two kinds—first, the establishment and maintenance of fundamental standards for all electrical measurements used in research and engineering (involving researches in the most refined methods of measurements and the most delicate and precise apparatus); and, secondly, engineering applications of electricity, including a limited amount of testing of commercial instruments and products. All this work is important for the business of war as well as that of peace. Important service was rendered to the military departments in the standardization of electrical equipment for military use, the formulation of proper specifications for the purchase and testing of such equipment, and the development of new and hitherto unavailable equipment for the new exigencies. The bureau made tests of electrical blasting devices for firing trench mortars and mines, and redesigned these machines with great reduction in their weight and cost and increase in their reliability. Extensive investigations of the electrical ignition systems for airplane and other gasoline engines have been carried out. This, combined with the bureau's work in ceramics, has resulted in a great improvement in the quality of spark plugs made in this country. An extensive comparison of magneto and battery systems of ignition has also been made with the promise of marked improvement. Specifications have been prepared and revised after experimental laboratory work under controlled temperature conditions. The large number of such batteries used for military purposes and the extreme importance of their unvarying and proper functioning make this problem one of unusual importance and urgency.

In the field of special illuminants the bureau was able to assist the military departments in developing trench flares, portable acetylene lights and field searchlights. The bureau is testing self-luminous paints. Radium has had direct application to military uses as a component of self-luminous materials employed extensively on the dials of aeronautic and other instruments used at night. In the important field of X-rays special attention has been given to the development of protective materials to safeguard the users of X-ray equipment, and gratifying results have been obtained in the improvement of this class of material. The novel

methods of magnetic analysis developed at the bureau for testing steel rails and other magnetic materials are now being used in testing steel for rifle barrels, with the object of materially speeding up the production of rifles.

Special equipment has been designed for the measurement of the velocity of projectiles, and the bureau has contributed in no small part to the methods now in regular use for this purpose. Another important field in which successful work has been done is the development of equipment for locating hostile batteries on land and for detecting subterranean sounds. In the field of radio communication the bureau has contributed the designs of various instruments, has made extensive tests of materials for use in such apparatus and has contributed large numbers of completed instruments. It has served also as a source of supply for highly trained men for the military radio service and has prepared circulars which are serving as the most-up-to-date textbooks in the service radio schools.

HEAT AND TEMPERATURE.

The important applications of heat measurements in the industries and the need for standardized equipment for this purpose have made the heat laboratories of the bureau of special service to industries engaged in the technology of materials and in technologic research generally.

An important investigation of the fire-resisting properties of structural materials has been conducted to furnish architects, construction engineers, builders, State and city building bureaus, insurance interests and others with basic data for the efficient design of structures with a view to a minimum fire loss. In the study of fire-resistive properties of materials structural steel columns were specially investigated. Many such columns with and without protective coating were tested in a specially devised furnace. The research showed that unprotected columns which would fail in half an hour, if properly protected by concrete or other material would remain intact for eight hours. The resistive properties of concrete columns was found to depend largely upon the aggregate used. Quartz aggregate proved specially resistive. Seventy-five steel and iron columns were tested during the year, all designed according to standard current practice with a view to excellent workmanship.

In addition to the above, 40 columns of reinforced concrete were submitted to fire test. The columns were subjected to pressure such as is encountered in structures and were mounted within a gas-fired furnace. Valuable results were obtained which will greatly aid in the effective design for similar columns in actual use. The column research is typical of the bureau's investigation of the fire-resistive properties of materials. It has already yielded valuable information and promises further results of importance to the building industries.

RESEARCHES ON METALS AND ALLOYS.

Metals are so vital a factor in the war that the division on metallurgy has been able to render important service. During the year a new building was completed for the metallurgical work, which is now installed in its new quarters. This laboratory contains a foundry, heat-treating and mechanical plant, rolling mill, power presses, shearing equipment, drawing bench for drawing metal tubes, and a machine shop, thus enabling the bureau to prepare and investigate alloys, both ferrous and nonferrous, of all kinds.

The year's work comprised the examination of gun metals, light alloys for aircraft, many alloys for special military uses, and pure metals required for technical purposes. The foundry has made 2249 separate experimental castings during the year. The recent development of light alloys has opened a new chapter in industrial work. The bureau researches on alloys were given special impetus by the visit of its chief expert to the battle front in France for the study of gun metals and aircraft alloys under war conditions. Light alloys are essential in aircraft, where both lightness and strength are required. It developed that metallurgists were unacquainted with the physiochemical data concerning aluminum and its remarkable series of special alloys. Circulars were, therefore, prepared for technical metallurgists and users of such alloys, and a consolidated circular on this important subject is in press. Many compositions in this series were cast and rolled for the bureau and studied in its laboratories.

Substantial progress has been made in the study of fusible metals, the melting points of which control the functioning of such devices as automatic fire sprinklers, safety plugs for steam boilers and others. The output of fusible tin plugs used as safety

devices in steam boilers is controlled as to quality by the bureau's researches. The work in metallurgy has covered numerous other subjects. Low tin solders, bronze and bearing metals have been developed to aid the War Industries Board in conserving of tin. The serious erosion of machine-gun barrels was the object of a special technical study.

Experimental work was done to establish standards of uniformity for the copper plugs used in testing powders. Standards of composition and thermal treatment were developed for the special metals used in aeronautic instruments.

In the research foundry methods were developed with respect to standard Government bronze, and details are soon to be published. Standards are being developed for molding sands which we believe will save 90 per cent of the so-called "burnt" sand. A standard method of determining carbon content of steel, devised during the year, permits complete determination in less than five minutes. A convenient method for determining nitrogen has also been devised, as well as new forms for determining other gases.

TESTING OF INSTRUMENTS AND MATERIALS.

Apart from scientific researches and technological studies, the bureau during the year has conducted thousands of tests, many of an investigative character. Examples, in round numbers, will indicate the magnitude of this work. About 18,000 thermometers were tested, including 13,000 clinical thermometers. About 200 tests of thermocouples and pyrometers for high-temperature measurements were made. The metallurgical division made 1289 thermal analyses, heat treatment and other kinds of metal tests, besides more than 2000 separate castings for experimental purposes. About 2000 tests on military optical instruments were made in the optical laboratories. The chemical work included 18,000 chemical tests during the year. It is now growing rapidly, and 30,000 tests will probably be made during the coming year. The bureau certified 3,500,000 barrels of cement for the Government departments and tested more than 5000 timepieces, nearly 3000 pieces of volumetric apparatus and 28,000 precision gauges.

MATERIALS.

The measurement and investigation of the properties of materials have in recent industrial practice become a vital neces-

sity. In no other way than by an exact knowledge of these properties can high efficiency be had. The successful war work of the bureau was possible because it had *already* studied the properties of materials used from a military point of view—for example, optical glass, light alloys, gun metal, cotton fabricated as substitute for linen in airplanes, low tin solders, and the like.

CHEMISTRY.

The chemical work of the bureau was transferred to the new chemical laboratory early during the year. The staff has expanded from 58 to 146, partly by the detail of chemists from the army to assist in military testing and research. The work has already outgrown its new quarters, and the laboratory is now housing 25 per cent. more work than was planned for it.

STANDARDIZATION OF SUGAR TECHNOLOGY.

Owing to the necessity of increasing to the greatest possible degree the American output of sugar, the entire machinery of the industry is overtaxed and upset. Many new problems demanding solution at the earliest possible date have arisen. Additional facilities and assistance were required to attack them. In order to begin the work Congress granted an appropriation of $20,000 to be used for the standardizing of sugar-testing apparatus and the development of technical specifications for the various grades of sugar with particular reference to problems made pressing by war conditions.

The United States has the largest and most diversified sugar industry in the world, including, as it does, the cane and beet industries, a great refining industry, a maple-sugar industry, a large sirup industry and a very important Government interest due to the collection of a revenue from an import duty. The widespread demand for technical assistance in these matters is shown by the fact that an entire edition of 1500 copies of the Bureau of Standards' circular was purchased by the public in less than three weeks.

THE BUREAU'S WORK FOR THE SOLDIER.

The applications of science to military uses are illustrated by several examples of the bureau's work directly affecting the comfort and efficiency of the soldier. The soldier's shoes are investi-

gated in the laboratory and in the field to determine the most suitable leather. A sole leather testing machine is used, and the leather is chemically investigated while controlled service tests are in progress by the soldiers in camp. The serviceability of shoestrings has also been under test. Uniform cloth has been under careful investigation for some time in the textile laboratories of the bureau. An expert was dispatched from the bureau to England and France to study the quality and serviceability of army uniform material, while in the laboratory the bureau has been making searching examinations of the various fabrics designed and submitted. It has assisted in developing and selecting from the available materials the present standard uniform button.

The heat conductivity of the soldier's blanket has been studied. Cotton blankets may equal wool blankets in this respect. The bureau has investigated shelter tents, the soldier's canteen and other kit equipment, washing and shaving soaps, combs, inks and other supplies for the soldier's use.

The bureau also determined by careful tests the most suitable trench oil stove, taking account not only of its heating efficiency, but the danger of observation from the light radiated on the ground. It has standardized the gauges for making the service rifle, has studied the problem of gun erosion and the failure of gun parts and material in service. All the men in the navy carry an identification tag devised by and prepared according to specifications developed by the Bureau of Standards. In short, there is scarcely a phase of the soldier's needs and activities in which the bureau has not coöperated with the military departments to secure the most effective provision for his comfort, convenience and fighting power.

THE METRIC SYSTEM.

The War Department early in the war decided to adopt the metric system for use in connection with maps and gun-firing data. The Ordnance Department has also adopted standard metric-dimensioned guns, such as the 37-millimeter, 75-millimeter and 155-millimeter models, and this involves corresponding changes in shell sizes. These uses of the metric system made it desirable that the Bureau of Standards issue for the information of the soldier a small manual.

ALUMINUM AND ITS LIGHT ALLOYS.*

THIS circular attempts to give all available information concerning the physical and mechanical properties of aluminum and its light alloys in summarized form. Commercial alloys are described and compared. The corrosion and disintegration of aluminum and its alloys is considered and the circular is concluded with a complete bibliography of the subject.

SILICA REFRACTORIES, FACTORS AFFECTING THEIR QUALITY AND METHODS OF TESTING THE RAW MATERIALS AND FINISHED WARE.†

[ABSTRACT.]

THE quartz or amorphous silica of raw silica brick is gradually transformed to crystal forms of lower specific gravity when the brick are burned, and subsequently when the brick are heated in use. This work was carried out primarily to obtain a means of simply yet accurately determining the degree to which this transformation has taken place in any given material. In the course of the work, however, some points concerning raw materials and method of manufacture have also been touched upon. The quartzites are first considered, then manufacture, and lastly properties of finished silica brick and methods of testing them.

By far the larger part of the silica brick manufactured in all countries are made from quartzites of comparatively early geologic age. Although in some cases amorphous (noncrystalline) silica, chalcedony, chert, and sand or pebbles cemented together with chalcedony have also been used. Suitable quartzites range from hard, highly metamorphosed varieties having tightly interlocking grains to medium soft rock, which is slightly porous. Loose grained quartzites and sandstones are, however, of little value. Quartzites that are now being used range from very young rocks back to the oldest sedimentaries.

As possible improvements (for certain materials) in the method of grinding and molding silica brick the use of sized material mixed in a machine similar to a batch concrete mixer to avoid further crushing of the grains as much as possible, and

* Bureau of Standards Circular No. 76.

† Technologic Papers No. 116.

machine molded with a pressure of approximately 1500 pounds per square inch is suggested.

Owing to the present tremendous demand for silica refractories, the tendency is to burn them as rapidly as possible to a temperature approximately equivalent to that required to cause Orton's pyrometric cone 18 to bend over. The experiments conducted in this study show that at temperatures from 1250° to 1350°C. there is a slight fluxing or drawing together of the particles of a raw brick, and that at these temperatures transformation of quartz to the forms of lower specific gravity takes place at a moderate rate. Thus, these temperatures insure minimum porosity and a medium rate of transformation. At higher temperatures, however, the transformation takes place rapidly, causing the porosity of the brick to increase unduly. The possible improvement in method of burning silica brick given below is based on the data gathered during the experiments, and is as follows. The temperature is gradually raised to 1250° C. in the usual manner and is then kept at from 1250° to 1350° C. for several days, at the end of which time it is gradually raised until cone 18 to 20 bends over.

The heating tests with raw commercial bricks brought out the fact that mixes made from the principal commercial quartzites all transform at approximately the same rate at temperatures from 1200° to 1500° C. and that the final specific gravities of all are very close together and in the neighborhood of 2.30. However, bricks made in the usual way from pure chert rock transform much more rapidly than do bricks made from quartzite, and the resulting brick is high in tridymite (crystal form of silica with specific gravity 2.270). Such chert brick when well burned, may prove of value in work which is subject to rapid changes of temperature. The heating tests also showed that the transformation taking place in commercially burned bricks on being reheated are essentially the same as those taking place in raw mixes. Thus, when underburned brick are heated for extended periods to 1200° C. or higher, as in byproduct coke ovens or gas benches, any quartz present will transform and cause an expansion of the exterior volume of the piece except as this expansion may be in part counteracted by drawing together of the particles of the brick due to soaking at high temperatures.

The specific gravities and porosities of most of the leading varieties of commercial silica brick have been determined, and all

varieties thus far tested have specific gravities between 2.650 (the specific gravity of quartz) and 2.270 (the specific gravity of tridymite). Brick made from chert rock, when well burned, have a specific gravity very close to this lower limit. The average specific gravity of all varieties so far tested is 2.384 and the average porosity of the same is 26.34 per cent. The limits of porosity found are 22.6 and 31.5 per cent.

The results of our own work in this connection and more recently that of other active operators in the testing of silica refractories, indicate that the relative position of the specific gravity of a silica brick between 2.65 and 2.270 is a definite indicator of the degree to which the brick has been burned, and in conjunction with the porosity, indicates approximately what the subsequent expansion of the brick will be in use. The porosity and specific gravity changes were obtained by computation from the dry weight of the piece, its weight when saturated with water and its weight when suspended in water. Thus, by a simple procedure the manufacturer can keep an accurate check on the nature of the silica brick he is turning out, and in the same way the consumer can determine what to expect from them in use.

Relation between Civil and Military Engineering. W. M. Black. (*The J. E. Aldred Lectures on Engineering Practice*, 1917–1918, Johns Hopkins University.)—The fundamentals of the course of study required for a civil engineer of all branches of the profession are the same as those for the military engineer. In military engineering, the officer entrusted with certain work must obtain beforehand all the information he can. He must then lay out the plan he hopes to follow, estimate probable difficulties to be met, and be ready to change this plan at short notice and adapt it to unexpected happenings. This involves a long and special training and a quickness of view and decision which are vital to the success of his work, especially in war. While the civil engineer does not often have to make the instant decisions of the military engineer engaged in actual war, he must, nevertheless, follow the same path in carefully planning his work ahead. In both cases—the civil and the military—the chief requisite to success is the careful study and choice of a suitable plan of work and the ability to meet the changes in conditions which always come. In military work at the front, any materials at hand must be utilized. Economy in cost must be disregarded; economy in time is the essential.

The ability to do certain things in a certain way without knowing clearly why that way is best, or even if it is the best, is poor preparation for an engineer. In the examinations of candidates for the position of Second Lieutenant in the Corps of Engineers of the Army which have been held for some years, some interesting facts have developed. All candidates must be graduates from some approved technical school, and the questions to be answered are such as should be answered by any man who has mastered his course. Yet the proportion passing these examinations is woefully small. At the last examination held, out of 190 candidates, the papers of only 36 could be accepted as up to or approaching the required standard. The failures were not in the most difficult studies only; topographical surveying frequently was a stumbling block. Descriptive geometry was so generally unknown as to create the impression that the value of this subject was underestimated by the schools themselves. It seemed at times as if the whole scheme of education had been at fault, that the scholars had never been compelled to undertake the tasks set and do the allotted work as a duty, whether congenial or not, and further, that the foundation of all, the general knowledge that every man that wants to attain success must have, was lacking.

Efficiency of Commercial Egg Candling. M. K. JENKINS and C. A. BENGSTON. (*U. S. Department of Agriculture, Bulletin 702*, September 12, 1918.)—It is common knowledge among those buying and selling eggs that grading by the candle is not an absolutely dependable method for the separation of good and bad eggs. As it is the best method known for determining the quality of eggs in the shell, however, it is important to learn its degree of efficiency.

The accuracy of candling depends upon the quality of the eggs and the skill of the candlers. With experienced workers, the number of bad eggs found in high-grade eggs after candling is negligible. On the other hand, when a large percentage of the good eggs in the supply have weak whites and yolks and when the percentage of bad eggs runs high, the difficulty of distinguishing between edible and inedible eggs is increased, and the number of bad eggs miscandled is greater. In studies with skilled candlers, the average number of bad eggs miscandled in a case of 30 dozen varied from 0.20 in spring firsts to 10.77 in very low grade refrigerator or cold-storage eggs. The number of bad eggs which could not be found by candling ranged from none to 6.93 per case, depending upon the grade examined. The data, as summarized from another point of view, show that out of 5,985 bad eggs present in 128,587 eggs, 71.65 per cent. were detected by candling, 17.02 per cent. were missed by candling, and 11.33 per cent. were not distinguishable by candling.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

THE PHYSICAL CHARACTERISTICS OF X-RAY FLUORESCENT INTENSIFYING SCREENS.[1]

By Millard B. Hodgson.

[ABSTRACT.]

THE use of fluorescent screens for the intensification of exposure is of widespread practice and of considerable importance in practical X-ray photography or roentgenology. Also in the work of Hull, St. John and others the fluorescent screen has been employed to reduce the lengthy exposures of such X-ray spectroscopic investigations that are dependent on the photographic plate for record.

In dealing with fluorescent phenomena dependent on an X-ray tube for excitation there are two types to be considered, both of which may be utilized for photographic intensification. The first type is that of true characteristic radiation, the second ultra-violet and visible fluorescent radiation. The true characteristic radiations of all the elements which are feasible to use are within that range of frequencies usually termed X-rays. Hence, the laws pertaining to high frequency radiation govern the photographic use of screens dependent on this principle. In the case of fluorescent emission of ordinary light the laws of ordinary optics apply.

Of these two types of intensifying screens, the second has proven the far more efficient in practical usage.

Of the materials which fluoresce to X-rays in the range of frequencies from the ultra-violet to the red, there are only a few which can be used efficiently for photographic intensification. All of these substances must be in crystalline state. Of these, crystalline calcium tungstate is by far the best with present photographic X-ray materials. The salt is usually powdered and coated with a suitable binder on a support of some material of slight X-ray absorption, such as cardboard or celluloid. This screen is then placed in contact with the photographic surface and exposure made through either the screen or the photographic plate or film.

* Communicated by the Director.

[1] Communication No. 67 from the Research Laboratory of the Eastman Kodak Company, published in *Physical Review*, December, 1918.

The efficiency of any radiator as a source of photographic stimulation depends primarily on the comparative spectral distribution of the energy of the radiator and the spectral sensibility of the particular photographic plates used. While these relations have not been determined as yet on an equal energy basis for X-ray materials, qualitative analyses have been made.

The fluorescent spectra of calcium tungstate were obtained, using a Hilger quartz spectrograph. A Coolidge tube of medium focus was used, the length of exposures averaging 1000 milliampere minutes at 8-inch distance from the target to the screen.

Spectrograms were made with the tube operating at 40 K. V., 60 K. V. and 80 K. V. (R. M. S.)

It was found in general the fluorescent spectrum of calcium tungstate as used in the screens examined extended from about 3600 to 5200 A. U. at the voltages normally used in radiographic practice. This emission coincides remarkably well with the wavelength sensibility waves of the X-ray plates which are being mostly used.

Testing Permanent Magnets by Means of a Voltmeter. ANON. (*Electrical World*, vol. lxxiii, No. 6, p. 267, February 8, 1919.)—In developing apparatus requiring permanent magnets, the National Safety Appliance Company of San Francisco found no suitable magnets on the market, and undertook to design, build and test large horseshoe magnets suitable for the work in hand. The magnets consisted of several laminations of $\frac{3}{16}$ inch by 3 inches by 60 inches forged magnet steel bent into U-shape and bolted together without air-gaps between the laminations. The laminations were bent with the 3-inch face parallel to the plane of the "U."

The magnetometer was built up from a direct-current voltmeter from which the permanent magnet had been removed. Soft Norway iron pole-pieces were fitted to the instrument, their outer ends projecting beyond its base and the inner portion connected in such a way as to take the place of the magnet supplied with the instrument. These pole-pieces were long enough to span the open end of the U-magnet. Tap-bolts were used to attach the magnets to the pole-pieces to secure good contact. A current of known strength was then caused to pass through the moving coil of the instrument, and the deflection of the pointer was read as directly proportional to the magnetic field set up by the magnet on the pole-pieces. The scale was divided into 100 spaces for convenience in taking the reading in terms of percentage of the strength of any magnet adopted as standard.

NOTES FROM THE RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY.*

THE ARRANGEMENT OF ELECTRONS IN ATOMS AND MOLECULES.

By Irving Langmuir.

In a paper to be submitted for publication in the *Journal of the American Chemical Society* a theory of the arrangement of electrons in atoms and molecules will be given. This theory, which is essentially an extension of Lewis' theory of the "cubical atom" (*Jour. Amer. Chem. Soc.* **38**, 762, 1916), may be most concisely stated in terms of the following postulates:

1. The electrons in atoms are either stationary or rotate, revolve or oscillate about definite positions in the atom. The most stable atoms, namely, those of the inert gases, have positions symmetrical with respect to a plane called the equatorial plane, passing through the nucleus at the center of the atom. No electrons lie in the equatorial plane. There is an axis of symmetry (polar axis) perpendicular to the plane through which four secondary planes of symmetry pass, forming angles of 45° with each other. These atoms thus have the symmetry of a teragonal crystal.

2. The electrons in any given atom are distributed through a series of concentric (nearly) spherical shells, all of equal thickness. Thus the mean radii of the shells form an arithmetric series 1, 2, 3, 4, and the effective areas are in the ratios $1 : 2^2 : 3^2 : 4^2$.

3. Each shell is divided into cellular spaces or cells occupying equal areas in their respective shells and distributed over the surface of the shells according to the symmetry required by postulate 1. The first shell thus contains 2 cells, the second 8, the third 18, and the fourth 32.

4. Each of the cells in the first shell can contain only one electron, but each other cell can contain either one or two. All the inner shells must have their full quotas of electrons before the outside shell can contain any. No cell in the outside layer can

* Communicated by the Director.

contain two electrons until all the other cells in this layer contain at least one.

5. Two electrons in the same cell do not repel nor attract one another with strong forces. This probably means that there is a magnetic attraction (Parson's magneton theory) which nearly counteracts the electrostatic repulsion.

6. When the number of electrons in the outside layer is small, the arrangement of the electrons is determined by the (magnetic?) attraction of the underlying electrons. But when the number of electrons increases, especially when the layer is nearly complete, the electrostatic repulsion of the underlying electrons and of those in the outside shell becomes predominant.

7. The stable and symmetrical arrangements of electrons corresponding to the inert gases are characterized by strong internal and weak external fields of force. The smaller the atomic number, the weaker the external field.

8. The most stable arrangement of electrons is that of the pair in the helium atom. A stable pair may also be held by: (a) a single hydrogen nucleus; (*b*) two hydrogen nuclei; (*c*) a hydrogen nucleus and the kernel of another atom; (*d*) two atomic kernels (very rare).

9. The next most stable arrangement of electrons is the *octet;* that is, a group of eight electrons like that in the second shell of the neon atom. Any atom with atomic number less than twenty, and which has more than three electrons in its outside layer tends to take up enough electrons to complete its octet.

10. Two octets may hold one ,two, or sometimes three pairs of electrons in common. One octet may share one, two, three or four pairs of its electrons with one, two, three or four other octets. One or more pairs of electrons in an octet may be shared by the corresponding number of hydrogen nuclei. No electron can be shared by more than two octets.

This theory explains the periodic properties of all the elements, including those of the eighth group and the rare earths. It also meets with success in explaining the magnetic properties of the elements, and, in fact, it applies as well to the so-called physical properties, such as boiling points, freezing points, electric conductivity, etc., as it does to the "chemical" properties. It leads to a simple theory of chemical valence applying equally well to polar and to non-polar substances. In the case of organic compounds

the results are identical with those of the ordinary valence theory, but with oxygen, nitrogen, chlorine, sulphur and phosphorus compounds the new theory applies as well as to organic compounds, while the ordinary valence theory fails completely.

This theory explains also the structure of compounds which, according to Werner's theory, are second order compounds with a coördination number equal to four. According to the present theory such compounds are to be regarded rather as typical primary valence compounds.

This valence theory is based on the following simple equation:

$$e = 8n - 2p$$

where e is the total number of available electrons in the shells of all the atoms in a molecule; n is the number of octets forming the outside shells, and p is the number of pairs of electrons held in common by the octets. This equation is a complete mathematical statement of the primary valence requirements, not only in organic but in inorganic chemistry.

The inert gases are those in which all the cells in the outside shell have equal numbers of electrons. Thus, according to the first four postulates, helium has two electrons, neon has ten, argon eighteen, krypton thirty-six, xenon fifty-four and niton eighty-six. All atoms with an atomic number greater than that of helium (2) have as their first shell a pair of electrons close to the nucleus. The line connecting the two electrons establishes the polar axis for the atom. Neon has in its second shell eight electrons, four in each hemisphere (*i .e.*, above and below the equatorial plane), arranged symetrically about the polar axis. The eight electrons are thus nearly at the corners of a cube. In argon there are eight more electrons in the second shell. In all elements of higher atomic number the second shell is like that in argon. Krypton has in its third shell nine electrons in each hemisphere, symmetrically placed with respect to the polar axis and to the four electrons in the second shell. The ninth electron in each hemisphere goes into the polar axis. This fact accounts for the position and properties of iron; cobalt and nickel. Xenon is like krypton, except that it has twice as many electrons in its third shell. Niton has sixteen electrons in each hemisphere of its fourth shell. These are easily placed symmetrically with respect to the polar axis and the eight underlying electrons.

This theory leads to very definite conceptions as to the positions

of the electrons in the molecules or space lattices of compounds. The structures of molecules of N_2, CO, HCN and NO prove to be exceptional in that the kernels of both atoms in the molecule are contained within a single octet. This accounts for the practically identical "physical" properties of nitrogen and carbon monoxide and for the abnormal inertness of molecular nitrogen.

The results obtained by the use of the postulates are so striking that one may safely reason that the results establish the fundamental correctness of the postulates.

These conclusions, however, are not easily reconciled with Bohr's theory of the atom. Bohr's stationary states have a rather close resemblance to the cellular structure postulated in the present theory. There are also striking points of similarity with J. J. Thomson's theory of the structure of atoms ,in which he assumes that the attractive forces are limited to certain tubes of force. It is probable, however, that the cellular structure is not so much a property of space as of the electron. It seems that the electron must be regarded as a complex structure which undergoes a series of discontinuous changes while it is being bound by the nucleus or kernel of an atom. There seems to be strong evidence that an electron can exert magnetic attractions on other electrons in the atom even when not revolving about the nucleus of the atom.

Paper Driving Belts. ANON. (*Machinery*, vol. xxv, No. 6, February, 1919, p. 497.)—It is said that paper driving belts have been introduced into German workshops. The paper is cut into narrow bands which are then spun, and the belts are made by weaving or braiding. Woven belts are of two kinds—paper fabric and paper thread—the fabric being more often used. The fabric is first cut into bands about 12 feet long, which are subsequently made into the desired width and thickness. A strengthening core is interposed, made of either cotton or sheet metal, though more recently the cores have been made of interwoven paper thread and metal wires. The core is encased in paper strips and the whole is then sewn with strong thread. These belts are said to be very flexible and to wear satisfactorily. The tensile strength is from 560 to 700 pounds per inch of width.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

CRYSTALLOGRAPHY AND OPTICAL PROPERTIES OF THREE ALDOPENTOSES.[1]

By Edgar T. Wherry.

[ABSTRACT.]

THE relations between chemical isomerism and the crystallography and optical properties in the aldopentose group of sugars has been studied. The α-*d* form of lyxose is monoclinic, with prism, front pinacoid, base, and back dome. The corresponding form of xylose is similar, the front pinacoid being absent. β-arabinose is rhombic, but the forms are similar to those on the other sugars, and there are striking similarities in the angles of the three, the angles of the prominent terminal forms and the ϕ angles of the dominant prism varying less than 2° from one to the other. The optical properties of these forms and also of α-arabinose were measured under the microscope by immersion method, using mixtures of turpentine, clove oil, and monobromnaphthalene of measured refractive indices differing by steps of 0.003, and varying the wave length of the light, obtaining the value for the D-line by interpolation. The results of observation are presented in a standard form which has been found most convenient in practice. A table of dispersions, giving the values of the three indices and the double refraction for six different wave lengths, is also presented. The specific gravities of the several forms were determined by suspension in carbon tetrachlorid and benzene, and from them the refractivities were calculated. The results for all four were practically identical, although they are distinctly less than the theoretical value. Finally, since it may be desirable to distinguish minute crystals of these sugars, a determinative table based on their optical properties is given.

* Communicated by the Chief of the Bureau.

[1] Published in *Jour. Amer. Chem. Soc.*, v. 40, Dec., 1918, p. 1852.

THE PRODUCTION AND CONSERVATION OF FATS AND OILS IN THE UNITED STATES.[1]

By H. S. Bailey.

Chemist in Charge, Oil, Fat and Wax Laboratory, Bureau of Chemistry, in collaboration with B. E. REUTER, Chief Fats and Oils Division, U. S. Food Administration.

[ABSTRACT.]

U. S. DEPARTMENT OF AGRICULTURE Bulletin 769, "Production and Conservation of Fats and Oils in the United States," recently issued by the Bureau of Chemistry, contains the first adequate survey of statistics on the fat and oil industry. These statistics, which were compiled by the U. S. Food Administration, cover the production, exportation and importation of fats and oils during the past seven years. The processes involved in making the various fats and oils are described briefly, and suggestions made for increasing the present supply and eliminating waste.

THE WEAR RESISTANCE OF LEATHER FROM DIFFERENT PARTS OF THE HIDE.[2]

By F. P. Veitch and J. S. Rogers.

[ABSTRACT.]

ACTUAL wearing experiments, involving 125 pairs of sandals and extending over a period of several months, were conducted with leather soles from different tannages and different sections of the hide. The total thickness of each sole worn away during a recorded number of hours' wear was determined and these results calculated to and expressed as inches wear per 1000 hours. The average losses were as follows: Butt (7 leathers), 0.464; heads (2 leathers), 0.512; shoulder (8 leathers), 0.605; belly (4 leathers), 0.944. Leather from the butt wore on an average at least twice as long as that from the belly portion of the hide, and about one and one-third times as long as that from the shoulder portion. While the results are but preliminary, they substantiate the belief which has been generally held for many years concerning the relative wear resistance of different sections of the hide.

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[1] Department of Agriculture Bulletin 769.

[2] Published in *J. Amer. Leather Chem. Assoc.*, vol. 13, No. 3, March, 1918, pp. 86–90.

THE GLOBULIN OF THE COCONUT, COCOS NUCIFERA. I. THE PREPARATION OF COCONUT GLOBULIN. DISTRIBUTION OF THE BASIC NITROGEN IN COCONUT GLOBULIN.[1]

By Carl O. Johns, A. J. Finks and C. E. F. Gersdorff.

THE globulin was extracted, by means of sodium chlorid solution, from coconut meal from which most of the oil had been removed by pressing. The yield was 10 per cent.

The distribution of the basic amino acids in coconut globulin as determined by the Van Slyke method was as follows:

Cystine	1.44 per cent.
Arginine	15.92 per cent.
Histidine	2.42 per cent.
Lysine	5.80 per cent.
Tryptophane	Present.

The percentage of free amino nitrogen on the unhydrolyzed protein was found to be 3.68 per cent. by the method of Van Slyke and Birchard.

Further work on the distribution of the mono-amino acids in coconut globulin is now in progress. Preliminary feeding experiments indicate that the proteins of the coconut are adequate for normal growth.

Latest Developments in the Electric Transmisison of Power. P. M. LINCOLN. (*Journal of the Cleveland Engineering Society*, vol. xi, No. 3, p. 153, November, 1918.)—For the long distance transmission of power there is to-day only one method that deserves serious consideration, and that is the electric method. There was a time when the direct current appeared to solve the problem of power transmission. The Brush arc-lighting generators, devised in the early days of electric lighting, were also devoted to some extent to the transmission of power, and the offshoot of that method of conveying electricity is responsible for the direct current installations in existence to-day.

Direct current transmission is not now employed in the United States, but there are some plants in Europe which are transmitting power by means of arrangements exactly similar to the Brush arc lamp system of 1878. That is, they are transmitting

[1] Published in *J Biol. Chem.*, vol. 37, No. 1, Jan., 1919.

power by using constant direct currents over a double line, and when the amount of power changes, the voltage changes. The Swiss engineer Thury is responsible for such direct current transmissions as exist now in the European countries. There are a number in Switzerland and a particularly large one in Southern France with a constant current of something like 500 amperes, and a voltage which at full load reaches 60 or 70 thousand volts; even with that, however, the amount of power distributed is relatively small. Present-day power units are very large. There is one plant in actual operation in the West where the generator units are 17,500 kilowatts each. There are some steam generators actually under construction and others projected of 100,000 horsepower and 75,000 kilowatts. When considering power of this order, the direct current system such as mentioned above is totally inadequate.

Brush first made his arc machine in 1878 and his method of lighting by arcs was developed very rapidly from that time on. The Edison incandescent system was first operated in the down-town section of New York City in 1882. The two methods were naturally considered for power transmission, but both of them fell a great deal short of meeting necessary requirements. The first alternating current transmission that took place in this country was carried on by William Stanley in 1885, who had become interested in the Goulard and Gibbs transformer which was being developed in France. Later the alternating current system was further developed by George Westinghouse, but the system would never have reached its present position without the development of the induction motor invented by Nikola Tesla.

After the year of 1890, the year of the introduction of the induction motor, the development of power transmission by alternating current was very rapid. It was in 1893 that there was put into operation at Pomona, California, a transmission line of about 30 miles at 10,000 volts. Then, in 1895, another 30-mile line was put in at 10,000 volts, and two years later the Telluride Power Company, in Western Colorado, doubled that voltage with 40,000 volts with a transmission distance of 55 miles. The 40,000 volts of the Telluride project remained the highest transmission voltage for five or six years. In 1903 at Guanajuati, Mexico, a transmission system was put in using 60,000 volts, the distance being 105 miles. Five years later, the voltage was increased at Muskegon, Michigan, to 100,000 volts. About four years later, the highest voltage yet installed of 150,000 volts was adopted by the Pacific Light and Power Company, from the mountain back of Fresco, California, to Los Angeles, a distance of about 240 miles. To date, that remains the highest that has yet been put into actual operation. However, 200,000 volts is being seriously considered by a number of companies, and probably not many years will pass before the 200,000 volt transmission will be in actual use.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, February 19, 1919.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 19, 1919.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report: 13.

Reports of progress were presented by the Committee on Library and the Committee on Science and the Arts.

The standing committees for the year 1919–1920 were announced.

Mr. Benjamin Franklin, Chairman of the Committee on Science and the Arts, introduced Mr. Tycho Van Aller, of Schenectady, New York, to whom had been awarded the Edward Longstreth Medal of Merit for his Calorizing Process. The President presented the medal and accompanying documents to Mr. Van Aller, who thanked the Institute for the honor conferred upon him.

The paper of the evening on "Oil Shales" was presented by Mr. Dean E. Winchester, Geologist, United States Geological Survey, Grand Valley, Colorado. An outline was given of the characteristics, distribution and value of the oil shales of the United States, together with a discussion of the origin of the oil that may be distilled from the shale. The methods of mining shales were described, as well as the various foreign and domestic processes for the extraction of the oil. Mention was also made of some of the by-products of this industry. A summary of the attempts now being made to develop a commercial oil shale industry was also given.

On motion of Mr. Franklin, duly seconded, the thanks of the meeting were extended to the speaker for his interesting paper.

Adjourned.

GEORGE A. HOADLEY,
Secretary pro tem.

STANDING COMMITTEES, 1919,

OF THE BOARD.

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A. E. Outerbridge, Jr.
Coleman Sellers, Jr.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, February 5, 1919.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 5, 1919.

DR. H. JERMAIN CREIGHTON *in the Chair.*

Mr. Benjamin Franklin was unanimously elected Chairman for the year 1919.

The following report was presented for final action:

No. 2727: Stabilized-Platform Weighing Scale. Mr. Frederick J. Schlink appeared before the Committee and explained the construction of the scale. Edward Longstreth Medal of Merit to Frederick J. Schlink, of Washington, D. C., adopted.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section and the Philadelphia Section of the Illuminating Engineering Society was held in the Hall of the Institute on Thursday evening, February 6, 1919, at 8 o'clock, with Dr. George A. Hoadley in the chair. The minutes of the previous meeting were read and approved.

C. E. Clewell, Assistant Professor of Electrical Engineering in the University of Pennsylvania, presented a communication on "Industrial Lighting." Modern industrial lighting was discussed, with special consideration of its physical and psychological aspects, and of its relation to industrial management, accident prevention, and wartime problems. Attention was paid to existing codes of factory lighting and their effective administration. The lecture was illustrated with lantern slides. A vote of thanks was extended to Professor Clewell. After some remarks by Doctor Hoadley, the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, February 19, 1919.)

RESIDENT.

MR. GEORGE W. LEWIS, Mechanical Engineer, 16 Princeton Avenue, Swarthmore, Pennsylvania.

MR. GEORGE SATTERTHWAITE, Manufacturer of Steel, in care of Tacony Steel Company, Tacony, Philadelphia, Pennsylvania.

MR. CLINTON F. SNYDER, Chemist, 1633 Locust Street, Philadelphia, Pennsylvania.

DR. F. E. STEWART, in charge of Pure Food Department, H. K. Mulford Company, Philadelphia, Pennsylvania.

NON-RESIDENT.

MR. HOWARD L. ADAMS, Managing Director, Keystone Institute, Reading, Pennsylvania.

MR. FREDERICK J. BLATZ, Leather Manufacturer, P. O. Box 967, Wilmington, Delaware.

DR. E. LEON CHAFFEE, Assistant Professor of Physics, Cruft Laboratory, Cambridge, Massachusetts.

MR. D. B. HEILMAN, Mechanical, Electrical and Chemical Engineer, Reading, Pennsylvania.

MR. ROY LINDEN HILL, Chemist, 619 East Broad Street, Tamaqua, Pennsylvania.

MR. ROBERT E. HORTON, Consulting Hydraulic Engineer, 57 North Pine Avenue, Albany, New York.

MR. EDMUND G. ROBINSON, Chemist, 1618 Broome Street, Wilmington, Delaware.

MR. L. T. SHERWOOD, Chemist, in care of du Pont Dye Works, Wilmington, Delaware.

MR. CHARLES F. SULZNER, Retired, 630 Fourteenth Street, Miami, Florida.

CHANGES OF ADDRESS.

MR. GORDON M. ATHERHOLT, in care of Atlantic Refining Company, Philadelphia, Pennsylvania.

MR. WALTER ATLEE, 1404 Massachusetts Avenue, N. W., Washington, District of Columbia.

MR. C. H. BERRY, 18 Washington Avenue, Detroit, Michigan.

LT. COMM. A. W. K. BILLINGS, Apartado 570, Barcelona, Spain.

MR. FREDERICK C. FEARING, 1614 Pennsylvania Building, Philadelphia, Pennsylvania.

LIEUT. A. H. GFRORER, in care of Lakewood Engineering Company, Cleveland, Ohio.

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DR. ENOCH KARRER, Bureau of Standards, Washington, District of Columbia.

MR. LUTHER D. LOVEKIN, Mill Creek Road, Ardmore, Pennsylvania.

MR. JOHN C. PARKER, in care of Lefax, Inc., Sheridan Building, Philadelphia, Pennsylvania.

MR. A. T. SMITH, in care of The Permutit Company, 440 Fourth Avenue, New York, New York.

DR. LESLIE D. SMITH, 5019 Walnut Street, Philadelphia, Pa.

MR. ERNEST STUTZ, 828 Stratford Avenue, South Pasadena, California.

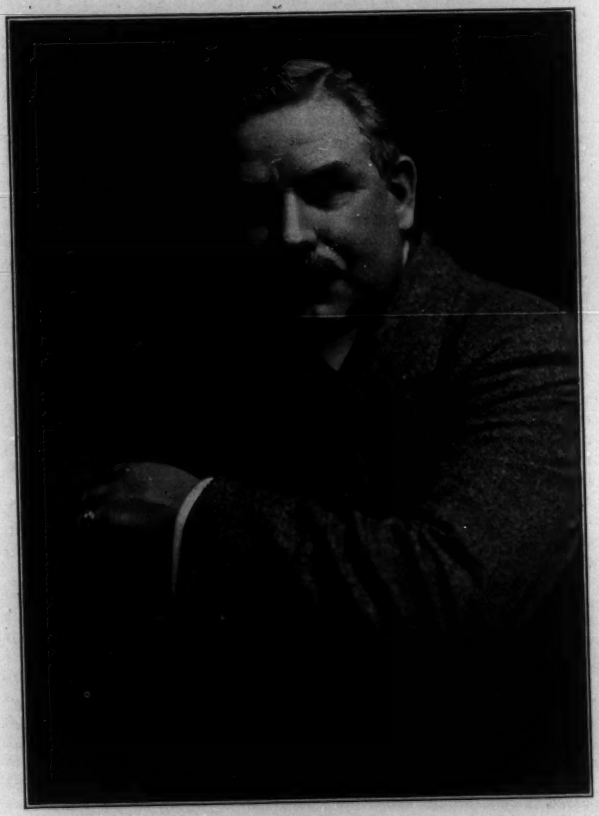
MR. R. JOHN TITZEL, 571 Lemon Street, Lancaster, Pennsylvania.

MR. FRANCIS R. WADLEIGH, 24 Broad Street, New York, New York.

MAJOR R. A. WIDDICOMBE, P. O. Box 1821, Washington, District of Columbia.

NECROLOGY.

Dr. Walter Victor Turner.—Dr. Walter Victor Turner, Manager of Engineering of the Westinghouse Air Brake Company, died at the Columbia Hospital, Wilkinsburg, Penna., Thursday morning, January 9, 1919, after a



WALTER V. TURNER
1866–1919

comparatively brief illness, due to a severe and sustained attack of Bright's disease. In the death of Doctor Turner the world has lost the greatest air brake expert of the age. Doctor Turner had a unique career. His work stands preëminent in its contribution to the safety of train movement and the development of transportation capacity in the way of longer trains, and higher speeds for both freight and passenger trains.

Doctor Turner was born in Epping Forest, Essex County, England, April 3, 1866. He engaged in the woollen textile business of that country, and came to America in 1888 to investigate the business of wool-growing in the West for the corporation with which he was associated. In 1893 he was made secretary and manager of the Lake Ranch Cattle Company, Raton, New Mexico. The venture flourished, and a little later he entered, with a partner, upon a similar business of his own. But in 1897, because of changed business conditions, this ended unsuccessfully. While still on the ranch a wrecked freight train had supplied him with a triple valve, which he appropriated and carried to his home, where, by candle light, his evenings were spent in exploring the mechanisms, passageways and functions of the valve, and he mastered its intricacies by inspection alone, without instruction.

He was then obliged to seek a position with the Atchison, Topeka and Santa Fé Railway as a car repairer, a position quite modest as compared with his previous one, but, because of its connection with railroading, one toward which he felt a strong attraction. The lure of the railroad appealed to his latent mechanical genius, giving promise of sure development into greater and higher usefulness. He advanced rapidly, becoming in one month gang foreman, and not long afterwards, chief car inspector. His work in the car department of the railroad naturally brought him into intimate contact with the air brake, which he was quick to recognize as an exceptionally ingenious and invaluable mechanism. The air brake enticed him, and he began an extensive study of its several parts.

He rapidly gained a reputation for proficiency in air brakes, and was placed in charge of the air brake instruction car on the Santa Fé road. From general air brake instructor he was promoted to mechanical instructor for the entire system, during this time having taken out twenty-two air brake patents.

In 1903 he entered the employ of the Westinghouse Air Brake Company as mechanical expert, applying himself to the betterment of existing apparatus and to improved devices with which to meet rapidly changing conditions of the times then occurring in both steam road and electric railway fields.

His advancement in his new work was consistent and rapid. He passed quickly through subordinate official positions and in 1907 was made Mechanical Engineer; in 1910, Chief Engineer; in 1915, Assistant Manager, and in 1916, Manager of Engineering.

One of his great achievements was the development of the K triple valve, of which there are now over two millions in use. This valve overcame many troubles incident to long freight train operation. Where before the operation of fifty freight cars per train with standard valves was con-

sidered the maximum by railways, the improvements embodied in the K valve made possible the air brake handling of freight trains from 100 to 125 cars per train. This, in turn, made possible greater traffic, heavier locomotives and higher capacity cars.

By his untiring energy and ingenuity, the braking of trains has been highly developed and perfected. Passenger trains which formerly required nearly 2000 feet to be stopped from a speed of sixty miles per hour, now stop in half that distance. On modern elevated and subway trains, the electro-pneumatic brake is stopping trains in a still shorter distance in proportion to speeds run. The most recently built New York subway has air brake equipment on its cars giving braking power automatically regulated by the entrance and exit of passengers to and from the car, and suitably changing the braking power of the car as the load carried reduces and increases. Thus a constant braking effect is provided regardless of the varying load carried by the car. These various electro-pneumatic brake devices have speeded up train service on all the subways and elevated roads where used. The empty and load brake he developed and perfected for freight service has greatly enlarged the traffic capacity of mountainous roads in permitting the safe operation of long and heavy freight trains on steep grades, and has improved the level road operation of trains of mixed loads. His great, continuing and ever-realized ambition was to make it possible to run two trains where but one could run before. In short, his contribution to the transportation industry of the world will always be an outstanding feature of its history.

He possessed a keen sense of differences, of essentials and degree. His marvelous knowledge of details and their proper proportion enabled him to lead the technical man and the less informed man with equal facility through the intricate maze of air brake problems.

He was a keen and liberal contributor of writings, lectures and discussion to scientific engineering and railway organizations and was the author of many books and papers regarded as air brake classics. Among the most notable of these is the paper he presented before The Franklin Institute in April, 1916, on "The Vital Relation Between Train Control and the Value of Steam and Electric Railway Properties."

He was awarded by The Franklin Institute the Edward Longstreth Medal of Medit in December, 1910, at the time he presented his paper on "The Air Brake as Related to Progress in Locomotion." As a recognition of his air brake inventions and developments he was awarded the Elliott Cresson Gold Medal by The Franklin Institute in May, 1912. He was made a fellow of the Royal Society of Arts of London in May, 1915, and as a further recognition of his achievements the degree of Doctor of Engineering was conferred on him by the University of Pittsburgh in May, 1918.

He was a member of the American Society of Mechanical Engineers, numerous social organizations, and practically all of the railway associations of this country.

He became a member of The Franklin Institute in November, 1910.

Mr. J. Sellers Bancroft, 917 Pine Street, Philadelphia, Pennsylvania.
Mr. Louis E. Levy, 1424 North Fifteenth Street, Philadelphia, Pennsylvania.
Mr. A. A. Robinson, 900 Tyler Street, Topeka, Kansas.
Mr. Raymond W. Tunnell, 15 North Fifth Street, Philadelphia, Pennsylvania.

LIBRARY NOTES.

PURCHASES.

American Concrete Institute.—Proceedings, vol. 14. 1918.
American Society for Testing Materials.—Proceedings, vol. 18. 1918.
BULLENS, D. K.—Steel and Its Heat Treatment. 1918.
International Catalogue of Scientific Literature. 5 vols. 1918.
JONES, F. D.—Mechanisms and Mechanical Movements. 1918.
MASON, W. P.—Water Supply. Considered Principally from a Sanitary Standpoint. 1916.
Mineral Industry.—Vol. 26. 1917.
Poor's Manual of Public Utilities.—Vol. 6. 1918.
Royal Society of Edinburgh. Transactions.—Vol. 52, pt. 1. 1918.
STEINHEIL, ADOLPH, and VOIT, ERNEST.—Applied Optics; The Computation of Optical Systems. 1918.
Thomas' Register of American Manufactures.—Vol. 10. 1919.
VILLAMIL, R. DE.—Resistance of Air, 1917.

BOOK NOTICES.

U. S. TARIFF COMMISSION, "DYES AND OTHER COAL-TAR CHEMICALS." Report to Congress Recommending Amendments to Title V of Act of September 8, 1916. 83 pages, 8vo. Washington, Government Printing Office, 1918.

This is a report to Congress by the Tariff Commission concerning changes that in the opinion of the Commission should be made in the division of the Act of September 8, 1916, technically termed "Title V." The changes are numerous and too complicated to be considered in the space here available, but those who are interested in the details of the tariff problem will be able by reading this pamphlet to see that the question involves as many conflicting interests as that of the League of Nations.

HENRY LEFFMANN.

THE NEW SCIENCE OF THE FUNDAMENTAL PHYSICS. By W. W. Strong, B.S., Ph.D., 107 pages, and table of contents, no index. Mechanicsburg, Pa., S. I. E. M. Company, 1918. Price, $1.25.

This is a profound study of the principles of physical science and is well worth perusal by those who are interested in that rapidly developing and complex field. It is certainly "caviare to the general." We are not informed whether the author is teaching science, nor the meaning of the mysterious initials indicating the publisher, but to the physicist the text will not be less attractive by reason of the lack of information on these points. Even the Preface shows a departure from conventionalities, for

it is dated "March 8–June 7, 1918." It is probably not to be assumed that the author took all this time to write it, but that this is the period devoted to the whole book. The work contains a good deal of recondite science mixed with some recondite theology and ethics. The following extracts from the last paragraph of the Preface and the last paragraph in the book, respectively, will serve to examplify these features:

"Events appear to hold the promise that the concentrated effort of peoples to win in a war will be replaced by a more unified aim to know life and nature and to apply this knowledge more fully to the service of man."

"It (the vision that nature has given us) brings us into a deep harmony with the Great Intelligence and we see in the way our efforts have rewarded us the measure of our image of Him and that it is the duty of man and of all his organizations to be blessed by the fullest communion and harmony with the Divine Plan." (A slight typographical error in the original has been corrected in this quoting.)

The latter sentence is part of the essay on the Relativity Theory. This theory is very abstruse and it is given to few to comprehend it. The reviewer is not one of these favored few, but he confesses that while he has gained some information from reading the chapter on relativity, he has read this closing sentence several times and cannot make anything of it.

HENRY LEFFMANN.

THE J. E. ALDRED LECTURES ON ENGINEERING PRACTICE, 1917–1918. The Johns Hopkins University, Department of Engineering. 236 pages, illustrations, 8vo. Baltimore, The Johns Hopkins Press, 1918. Price, $1.00.

These lectures are the second series given for the undergraduates of the University by the gift of Mr. J. E. Aldred. They deal with the practical phases of engineering work and are designed to lead the student to an appreciation of the methods of professional practice. The following representative subjects are covered: Steam-Electric Power Plant Design; The Relation Between Civil and Military Engineering; The Development of Concrete Road Construction; Copper Refining; The Coal Problem; The Growth of Electric Systems; The Control of Stream Pollution; The Manufacture of Structural Steel.

A periodic contact of this kind with important engineering projects should prove a material aid in giving the student a clear conception of the ends towards which his studies are being applied.

LUCIEN E. PICOLET.

A HANDBOOK OF COLLOIDAL-CHEMISTRY. By Dr. Wolfgang Ostwald. Second English edition, translated from the third German edition by Dr. Martin H. Fischer, of the University of Cincinnati, with numerous notes added by Emil Hatschek, of the Cass Institute, London. 271 pages, contents and index, and 63 illustrations, 8vo. Philadelphia, P. Blakiston's Son & Company, 1918. Price, $3.50 net.

The value of this work can be best exhibited by an extract from the preface to this edition: "Yielding to pressure from the publishers, who find need at this time for a new printing of this volume, we have reluc-

tantly met their request to revise and bring up to date the original translation, as made by one of us with the assistance of Ralph E. Osper and Louis Berman. . . . . We have met the situation by leaving untouched those large portions of the volume which contain the author's individual views." It is evident that the work fills satisfactorily a great need in chemistry in this country and England, and it is very sad to think of the developments which have compelled competent translators to make the apology which is easily detected in the above quotation. "Quis talia fando Myrmidonum, Dolopumve aut duri miles Ulyssei temperet a lacrimis."

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

A Handbook of Colloid-Chemistry: The Recognition of Colloids, the Theory of Colloids, and Their General Physico-Chemical Properties, by Dr. Wolfgang Ostwald. Second English edition, translated from the third German edition, by Dr. Martin H. Fischer, with numerous notes added by Emil Hatschek. 284 pages, illustrations, 8vo. Philadelphia, P. Blakiston's Son & Company, no date.

Screw Threads: Bibliography of Available Material on the Systems and Classification of Screw Threads, Including Tolerances, Allowances and Symbols of Nomenclature; and on Gauges, Methods of Testing, and Specifications Prepared at the Request of U.S. Screw Thread Commission and Arranged in Alphabetical Order According to Authors and Titles, and With an Index by Henry E. Haferkorn. Supplement No. 2, Professional Memoirs, November–December, 1918. 62 pages, 8vo. Washington Barracks, D. C., Engineer School, 1918.

U. S. Bureau of Mines: Bulletin 170. Extinguishing and Preventing Oil and Gas Fires, by C. P. Bowie. 50 pages, illustrations, plates, 8vo. Technical paper 152. The Inflammability of Aluminum Dust, by Alan Leighton. 15 pages, 8vo. Technical paper 196. Notes on the Black Sand Deposits of Southern Oregon and Northern California, by R. R. Hornor. 42 pages, illustrations, plates, maps, 8vo. Washington, Government Printing Office, 1918.

United States Tariff Commission: Second Annual Report, Fiscal Year ended June 30, 1918. 118 pages, 8vo. Washington, Government Printing Office, 1919.

U. S. Coast and Geodetic Survey: Results of Observations Made at the United States Coast and Geodetic Survey Magnetic Observatory at Vieques, P. R., 1915 and 1916, by Daniel L. Hazard. 100 pages, plates, quarto. Results of Observations Made at the United States Coast and Geodetic Survey Magnetic Observatory at Cheltenham, Md., 1915 and 1916. Washington, Government Printing Office, 1918.

U. S. House of Representatives: In Matter of Investigation of Packing Industry. Testimony of J. Ogden Armour on Behalf of Armour & Company, Jan. 21, 1919, Before Committee on Interstate and Foreign Commerce. 68 pages.

U. S. Reclamation Service: Work and Homes for Our Fighting Men. 24 pages, illustrations, 8vo. Washington, Government Printing Office, 1919.

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For further information and membership application blanks address the SECRETARY of THE INSTITUTE.

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The Franklin Medal (Gold Medal and Diploma).—This medal is awarded annually from the Franklin Medal Fund, founded January 1, 1914, by Samuel Insull, Esq., to those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Institute, acting through its Committee on Science and the Arts, have done most to advance a knowledge of physical science or its applications.

The Elliott Cresson Medal (Gold Medal and Diploma).—This medal is awarded for discovery or original research, adding to the sum of human knowledge, irrespective of commercial value; leading and practical utilizations of discovery; and invention, methods or products embodying substantial elements of leadership in their respective classes, or unusual skill or perfection in workmanship.

The Howard N. Potts Medal (Gold Medal and Diploma).—This medal is awarded for distinguished work in science or the arts; important development of previous basic discoveries; inventions or products of superior excellence or utilizing important principles; and for papers of especial merit that have been presented to the Institute and published in its JOURNAL.

The Edward Longstreth Medal of Merit (Silver Medal and Diploma).—This medal, with a money premium when the accumulated interest of the fund permits, is awarded for meritorious work in science or the arts; including papers relating to such subjects originally read before the Institute, and papers presented to the Institute and published in its JOURNAL. In the event of an accumulation of the fund for medals beyond the sum of one hundred dollars, it is competent for the Committee on Science and the Arts to offer from such surplus a money premium for some special work on any mechanical or scientific subject that is considered of sufficient importance, or for meritorious papers presented to the Institute and published in its JOURNAL.

The Certificate of Merit.—A Certificate of Merit is awarded to persons adjudged worthy thereof for their inventions, discoveries or productions.

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